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THE BRITISH JOURNAL OF METALS

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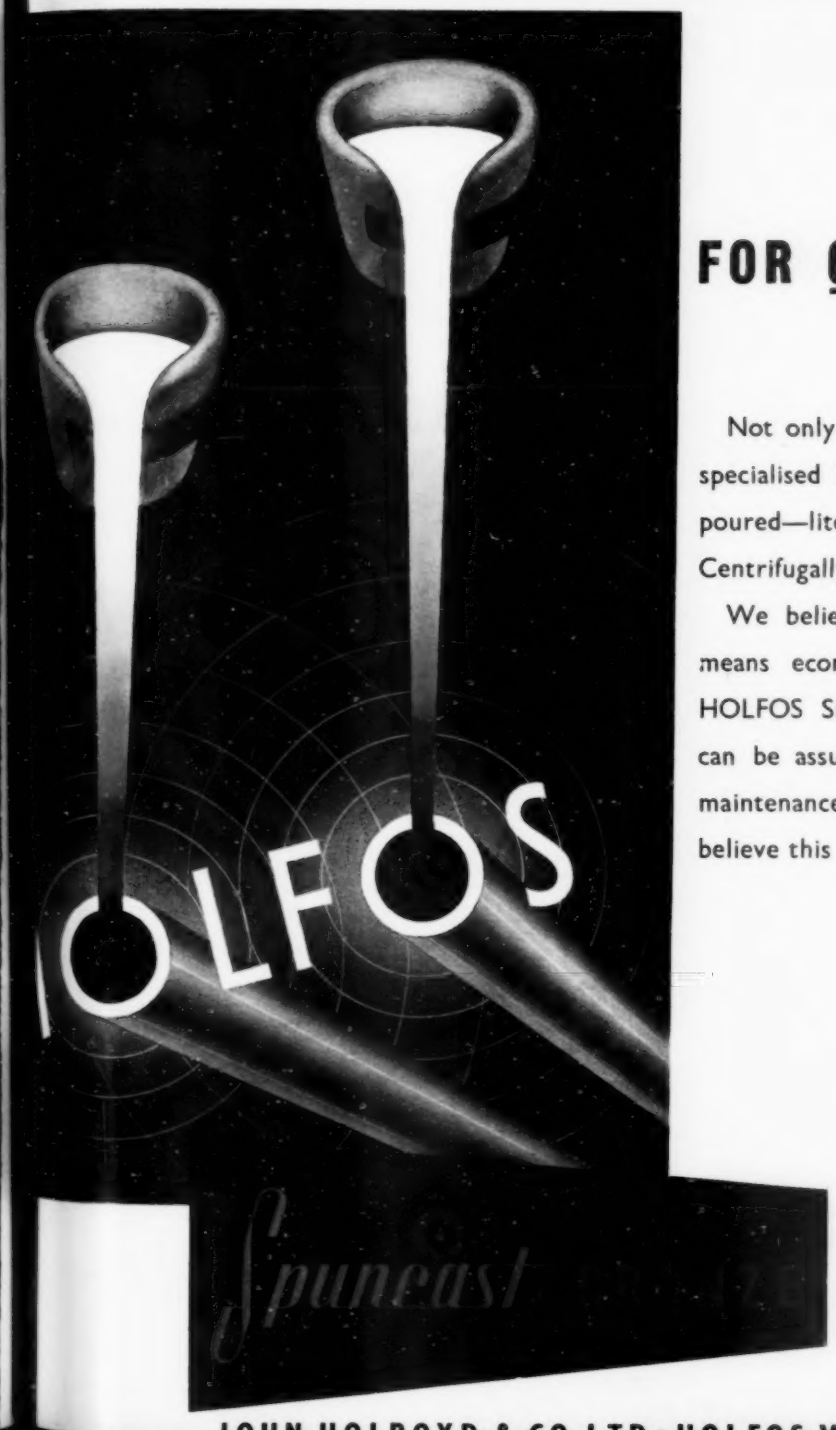

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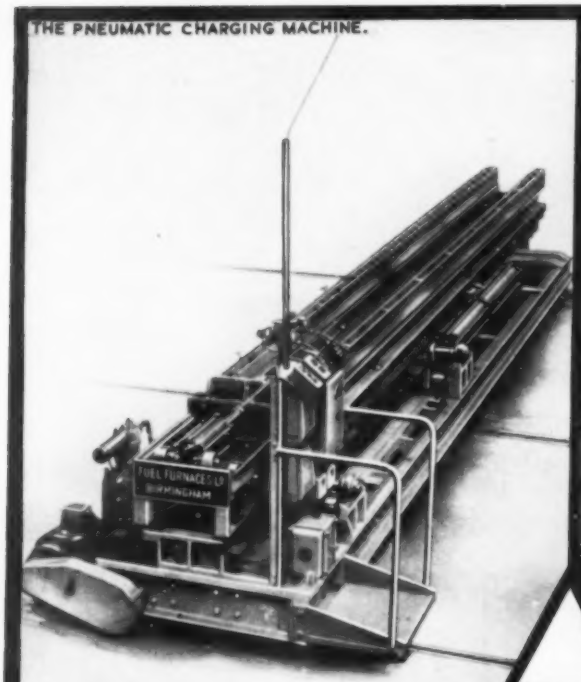

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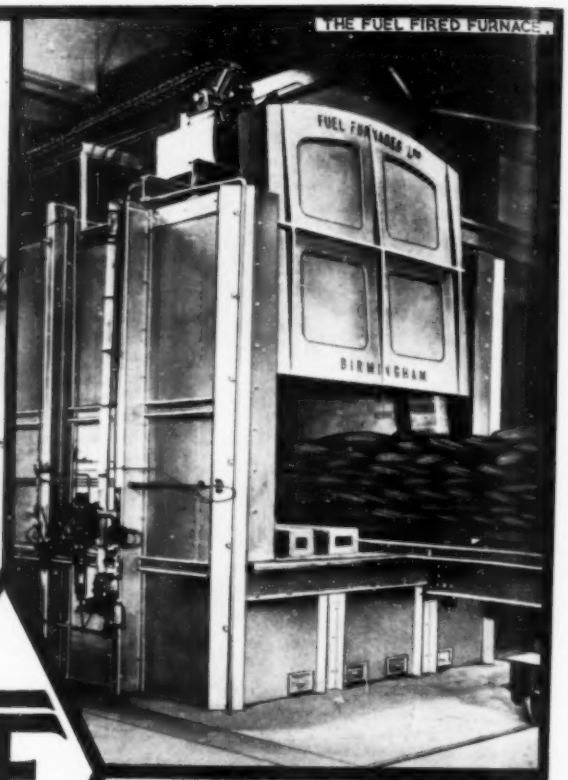

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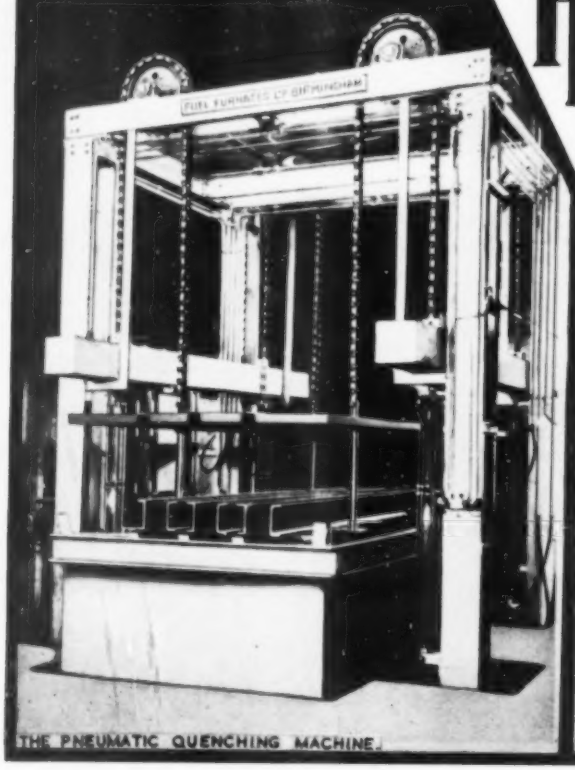

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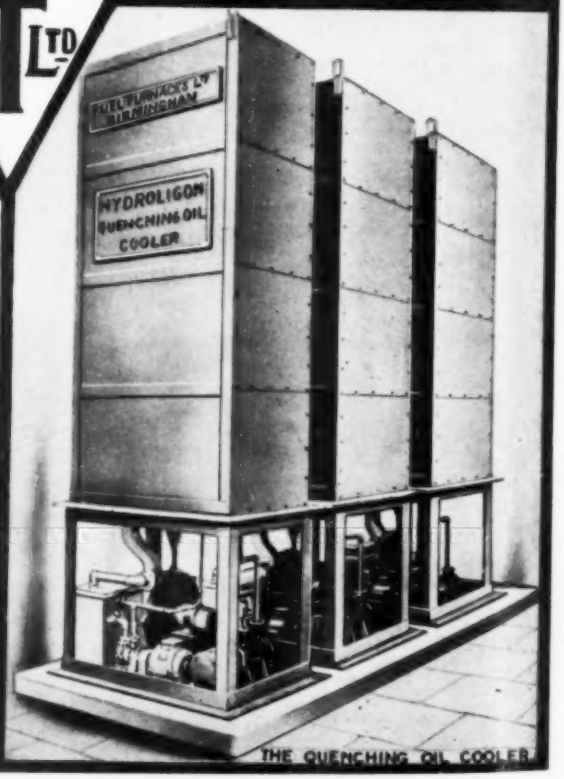

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THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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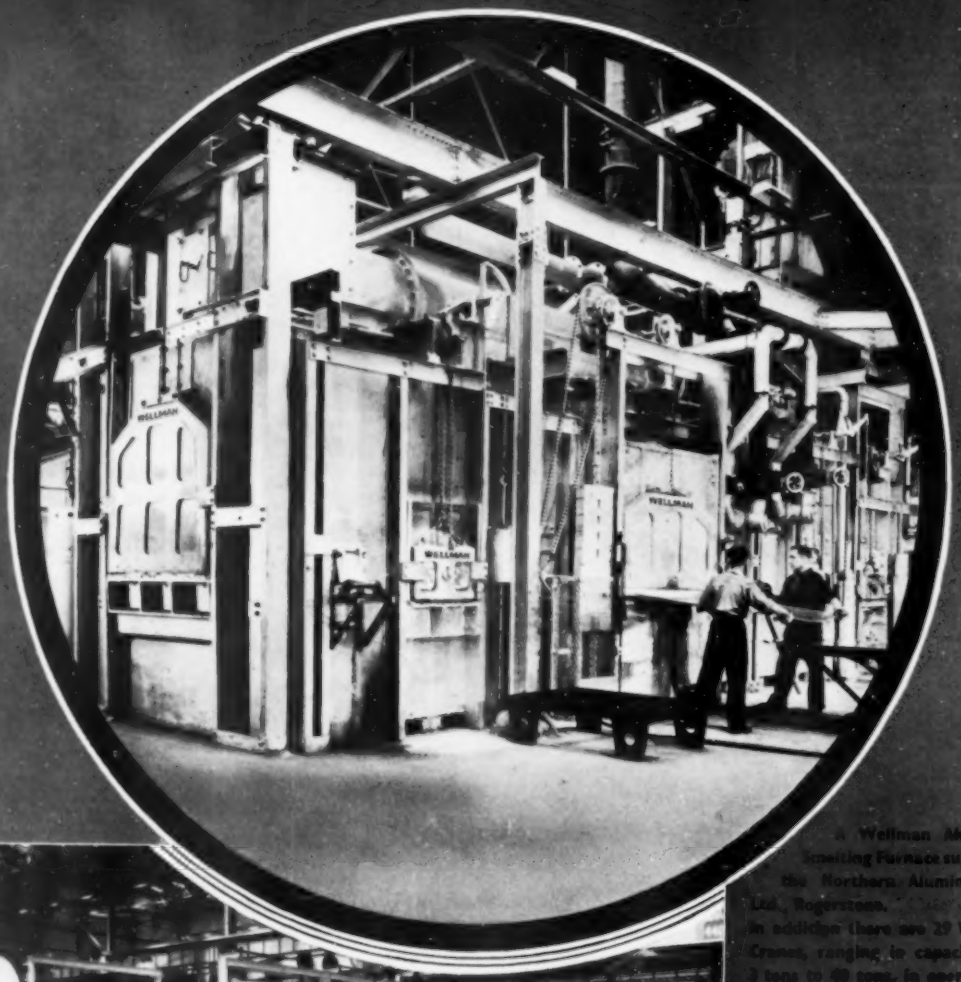
WELLMAN

Furnaces and Mechanical Handling Equipment



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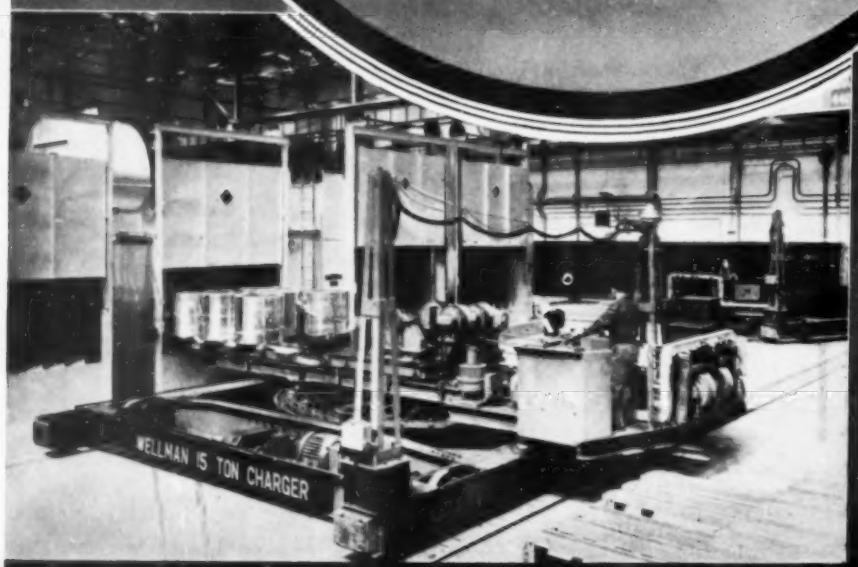

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

JUNE, 1956 Vol. LIII. No. 320

Machine Tools

IN a now famous speech, Mr. R. A. Butler, when he was Chancellor of the Exchequer, said that by "investing in success," we could double our standard of living in 25 years. With a view to studying how this desirable object can be achieved, the Institution of Production Engineers arranged, in connection with its recent Exhibition at Olympia, a Conference which had as its theme "Investing in Success." At the outset, Mr. H. F. Spencer, Managing Director, Richard Thomas & Baldwins, Ltd., and Chairman of Council, British Institute of Management, pointed out that, at our present slow rate of progress, the rise in living standards in the next quarter century is more likely to be of the order of 20%, not 100%. The possibility of doubling the standard of living in this period presupposes, therefore, an industrial efficiency and sufficiency over all our economy which may call for sacrifices in personal consumption at home—certainly great discipline in consumption—over the years ahead, rather than early increases. Moreover, the achievement of such industrial efficiency and sufficiency would be of infinitely more significance and value as an assurance of our survival in a competitive world, than as a measure of the satisfaction of personal desires at twice as high a standard of material well-being.

During the period of the Conference, speakers discussed the benefits of "investing in," among others, such varied things as international co-operation for productivity; better fuel utilisation; education and training; better quality control and inspection; better human relations; and automation. One paper of particular interest was that by Sir Stanley Rawson, Chairman, Wickman, Ltd., and Vice-Chairman, John Brown & Co., Ltd., on "Investing in Better Machine Tools," as at the end of this month the four-yearly exhibition organised by the Machine Tool Trades Association is being staged in London.

As Sir Stanley points out, machine tools are the instruments by which not only metals but all similar products of art are given the shapes and forms in which we need them. Moreover, the machine tool has come to be recognised as the instrument of advanced production. It can, perhaps, best be defined as a device by which an applied skill can effect a geometrical and not an arithmetical improvement in production. Speed, accuracy, and consistency or repeatability are the functions of the machine tool, and should not be merely the result of the manoeuvres of the operator. Although in a paper with such a title, the costing aspect naturally comes in for lengthy consideration, an indication is given of certain aspects of technical progress in this field.

One of the factors which has contributed greatly to the improvement in machine tools has been the production as a matter of course of metals homogeneous and uniform in properties, and with known and predictable physical properties. This has influenced both the construction of the machine and its performance, since the removal of the problem of irregularity of materials makes it possible to predict with confidence how a machine tool should run to remove most economically a given amount of material. This does not, of course, mean that all cutting problems have been solved. New materials bring with them new difficulties, an outstanding example being the machining of gas turbine blades in the newly developed heat resisting materials. In a decade or so, the machining of such materials will be commonplace, and new problems will have taken the place of those of today. Before the war, only some 15% of the machine tools of the country could make effective use of hard metal tools, whereas today, probably less than 15% cannot. For many present day applications, the limit of cutting capacity of a hard metal tool is the strength of the bond between the tip and the shank, and new methods of attachment or application are being devised. Moreover, new cutting materials, which represent a great advance on present materials, are already in sight.

Another factor which has played an important part in the development of better machine tools has been the improvement in gear design and production, and the substitution of hydraulic or electrical controls. These changes have reduced considerably, if not eliminated, irregularities resulting from intermittent shock in the mechanical transmission to the cutting tools. This is a most important point, as increased speed of cutting is valueless if time-consuming rectification in the fitting shop is a normal consequence.

The introduction of the copying lathe and the profiling miller, with either built-in or detachable copying devices, has brought repetition machining to a point where quite a small number of pieces justifies the use of copying methods, even where the pieces themselves are simple in outline. In most jobbing shops, a copying attachment to a centre lathe would be most useful, and as these devices can work from a master piece or a template, their convenience and adaptability are very good.

Sir Stanley also draws attention to the efforts now being made on an international scale to build up a unified conception of the significance and function of machine tool testing. In any articulated structure, minor irregularities can often be compensated for in the finished and completed whole, and it is in the performance of the completed whole that the machine tool buyer is interested. On the other hand, whilst it may be true that one may not make a good machine out of exactly dimensioned parts, one's chance of doing so is far better than if one indulges in hit-or-miss construction. The experience of the leading members of the U.S. machine tool industry in meeting the demand of the automobile industry for consistent and accurate machining has brought on immense improvement in the effectiveness and performance of their machines, and insistence upon accuracy in detail parts is the necessary preliminary to satisfactory wholes.

In the Birthday Honours List

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A. B. MANN, O.B.E., Chief Mechanical and Electrical Engineer, Ministry of Works.

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D. R. E. O'NEILL, Technical Sales Manager, The London Aluminium Co., Ltd.

G. S. PALMER, Manager, Titanium Melting Plant, William Jessop and Sons, Ltd.

Continued on page 248

The Invention of the Bessemer Process

Mr. James Mitchell's Centenary Lecture

Although a man whose inventions ranged from a method of producing bronze powder to a ship's saloon designed to conquer sea-sickness, Sir Henry Bessemer's greatest influence on the life of his own and subsequent generations undoubtedly resulted from his invention in 1856 of what is universally known as the Bessemer process of steelmaking. To mark the centenary of this landmark in the history of the iron and steel industry, an exhibition of Bessemer relics was arranged in connection with the Annual General Meeting of the Iron and Steel Institute, and Mr. James Mitchell, C.B.E., delivered a Bessemer Centenary Lecture at the Royal Institution on the evening of Tuesday, 15th May, 1956. That part of the lecture dealing with the development of the Bessemer process is presented here in a slightly abridged form.

IT may help in assessing the importance of Bessemer's invention of a new steelmaking process to consider the conditions prevailing at the time it was made. The engineer of a hundred years ago could make a casting from the available relatively brittle and non-malleable pig iron ; the bridge-builder or shipbuilder could make a bridge or ship with malleable iron ; whilst the cutler or instrument maker could make tools, cutlery or instruments from the appropriate commercial form of steel; but there were at least two all-important limitations on these activities—the methods of producing malleable iron and steel were not only relatively costly, but were also such that an increase of production on a major scale was impracticable. The Bessemer process of steel production, therefore, not only provided less costly materials for existing uses but made possible an unlimited expansion of production. These advantages accrued to a civilization which was at the point of expanding rapidly in engineering, railways, and shipbuilding : in fact, in all those activities which today depend on the steel industry for their raw materials. It was an American commentator, Abraham S. Hewitt, who said : "... the Bessemer invention takes rank with the great events which have changed the face of society since the Middle Ages. The invention of printing, the construction of the magnetic compass, the discovery of America, and the introduction of the steam engine are the only capital events in modern history which belong to the same category as the Bessemer process."

The story of how Bessemer became interested in ferrous materials and their properties, in the first instance, is well known. He had invented a rotating projectile, the propulsion of which in the required direction for the required distances proved too much for the cast-iron cannon of that day. As has happened on other occasions, the engineer was awaiting the next advance of the metallurgist. The engineer in this case was not prepared to do the waiting, and Bessemer regarded the need for better material for ordnance as a personal challenge. That he acted with celerity may be seen from a look at dates. Tests on his rotating projectile took place in France in December, 1854, and on 10th January, 1855, we find in the records of the Patent Office Bessemer's first application for "Improvements in the Manufacture of Iron and Steel"—characteristic of the energy and promptitude with which, throughout a long life, he attacked a multitude of problems. There followed about eighteen months of intense experimental activity, and on 11th August, 1856, at a British Association Meeting at Cheltenham, Bessemer read a paper on "The Manufacture of Iron without Fuel." It was a provocative title, and, bearing in mind the limited technical practices of the day, it described a startling technique : the proposal to blow cold air through molten iron and finish up with material hotter than that with which one started and with a ductile and malleable product instead of a hard brittle one must have come as a considerable shock to the ironmasters and engineers of 1856.

Paper Published in Newspaper

Not a few people went to the meeting to scoff and remained, if not to pray, at least to praise. It was this underestimate of its importance which, indirectly, led to the publication in full of this historic paper in *The Times* newspaper. Their correspondent at the British Association Meeting confessed to Bessemer that, largely owing to the jocular comments he had heard before the reading, he had not taken as full a report as he wished. If Bessemer would lend him a copy he promised that it would appear in full in *The Times*. This it did in the issue of 14th August, 1856, thus ensuring to that journal what, in the light of after-events and in the slang of today, would be called a "scoop." If a journalist of that day was impressed to this extent by the change in the atmosphere during the meeting, how great must that have been.

There are two main themes running all through the paper : the production of malleable iron which was much better than anything then known, and the achievement of the high temperature necessary to melt this without extraneous heat. These, together with the method, were the burden of Bessemer's disclosure. The description of the apparatus reads like a patent specification, from which it may well have been taken—there is a wealth of meticulous detail. The advantages of the product over wrought iron are dealt with in what, for the ironmasters of the day, must have seemed minatory terms—freedom from slag, unlimited size, no hard spots, better rolling properties and so forth.

The reader of the paper today is immediately struck with the awareness of the lines on which the method must, and indeed did, ultimately develop. Practically all the important matters having a bearing either on the product or the process are mentioned. It is stated that, whilst primarily the method produces fluid malleable iron which can be cast and worked, free from all the deficiencies of the puddled iron of the day, the possibility of a range of material of varying carbon content, from traces to cast-iron proportions, is clearly indicated. The ability to produce large masses of any quality for engineering work is specially noted, whilst the economic

advantages of the largest-scale production possible are recognised, as is the need to have all operations of a series in what today is called an integrated plant, properly balanced.

The recovery of iron pellets from the slag or from the converter ejections is recommended, and the use of scrap, even down to the thrifty use of waste-heat methods of preheating it, is clearly described. All these aspects of almost universal applicability were appreciated by one whose experience of the iron industry was of months', rather than of years' duration, and at a time when the steel industry, as we know it today, was as yet hardly born! This paper was indeed the charter on which it was founded, and the completeness of its statement of general principles is a major tribute to Bessemer's perspicacity and prescience.

Some of the explanations advanced in giving a very graphic description of the blow may not stand up to modern metallurgical theory, but there is no doubt that he had a fairly clear idea, in general terms, of what happened when iron was blown down to steel.

Early Setback

Coming down to a more mundane plane, there remains one other outstanding feature of the paper—its claim to be regarded as a very fine effort in salesmanship. Proof of this, if proof were necessary, comes from the number of licences which were taken up within a few weeks of the meeting. Five separate firms in widely dispersed areas took up licences to make iron by the new process from their own available pig-iron supplies. They paid, in all, £27,000. There was at least one other who attempted to operate the process without this formality. In all cases, however, the results were the same. The first halcyon flush of enthusiasm was over and, in each case, to quote Bessemer himself, ". . . the results of the trials were most disastrous." Brittle when cold, unworkable when hot, the metal produced showed no resemblance to the sample bars which Bessemer had made in his trial furnace, and which he had exhibited with such justifiable pride at the British Association Meeting.

This setback was the prelude to two to three years of hard and unrewarding labour. In fact, it took rather longer to define the limits of the process than it had taken to evolve it in the first place. The composition of the pig iron was an obvious starting point, and from there Bessemer set out on his quest. It is perhaps difficult for us, used as we are to analysis figures obtained in a matter of minutes, to appreciate the time which such an investigation would take one hundred years ago, especially when the actual cause of the trouble was unknown. The analytical efforts of 'a well-known Professor of Chemistry' at last made it clear that phosphorus was one of the impurities which accounted for the unsatisfactory nature of the product and the apparent failure of the process. This discovery was followed by a futile experimental campaign designed to remove phosphorus: blowing gases (hydrogen, methane, etc.) through the metal was tried, as was the use of fluxes. The advocates of the ultra-scientific approach to technical problems will find a considerable amount of ammunition against empiricism in the efforts of Bessemer at this time. In the end the problem was left to be solved twenty years later by the genius of Sidney Gilchrist Thomas, and Bessemer turned his attention to the production of low-phosphorus irons as a starting point. Whilst engaged in the quest for low-phosphorus and low-sulphur British iron, Bessemer decided to import a quantity of Swedish charcoal pig iron, which was known to be low in these elements. He had obviously two ends in view: (i) to confirm that phosphorus was the element he must remove, and (ii) to re-assure himself that he had in fact a practicable process, and that he was not chasing some mirage which had led him into a particularly baffling and unprofitable desert. The Swedish iron when it arrived fulfilled both these ends; the metal was successfully converted into pure soft malleable iron, and also into steel of various degrees of hardness. This last phase calls for special remark. It is true that in his paper Bessemer foresaw the possibility of making a wide range of iron-carbon alloys, but this is the first note that he had in fact done so. From this point onwards, the emphasis is on steel rather than on iron. It is doubtful if at this stage, at least, Bessemer appreciated how far the success of these tests rested upon the relatively high manganese content of the Swedish iron. This not only made the direct production of steels of varying carbon content possible, but avoided failure due to red-shortness when the metal was blown down to 'soft malleable iron.' If, in fact, he had made the low-phosphorus trials with an iron low in manganese, he might well have had to wait a still longer time before emitting the well-justified whoop of triumph with which he saluted the results of the Swedish-iron trials. If it had happened that he had received supplies of low-phosphorus British iron, low in manganese, before the Swedish deliveries, these, when they came, would have underlined the importance of manganese, although the fact that the Swedish iron was 'charcoal' iron might well have drawn yet another red herring across his path.

There was certainly an element of good fortune in the circumstances which led to the purchase of the original experimental iron from a London ironfounder who sent him ". . . grey Blaenavon iron which he was then using in his business, and which I accepted simply as pig iron, without ever suspecting that pig iron from other sources was so different, and would give such contrary results."

Bessemer in several places in his writings notes the advantages accruing from his comparative ignorance of metallurgy. There is no doubt that this is true as far as the initial approach to his problem was concerned, but it is just as certain that even a small modicum of the then available knowledge would, in the later stages, have eliminated months of doubt and uncertainty, e.g., the reason for the non-removal of phosphorus was pointed out by Gruner of Paris as early as 1857.

To say, as we must, that in some degree Bessemer owed something to others is not to detract in any way from the magnitude of his own contribution. This would seem to be an appropriate point at which to consider what Bessemer owed to two others whose names should be remembered at this Centenary time—Göran Frederick Göransson and Robert F. Mushet.

Control of Carbon

Göransson was a leading Swedish ironmaster who had bought part of the Swedish Bessemer patent in June, 1857. He was supplied with plant, converter, and blowing engine by Bessemer, but had great trouble in achieving successful operation. He finally scrapped the converter supplied and erected a fixed vessel of the same kind as that used in Bessemer's original experiments. After many disappointments and failures relating to the quantity and pressure of air supply, successful operation

was achieved on 19th July, 1858. The practice adopted was to obtain varying grades of steel by stopping blowing at the required carbon. As the metal was high in manganese no final addition was required. The only difficulty was to know when to stop. Göransson himself stated that Professor Eggertz's carbon test, the practice of which in thousands of steelworks laboratories at a later date was to become the starting point of many a steelworks metallurgical career, finally solved the difficulty. This test was developed about 1861 and was first described in 1862, and was no doubt evolved to meet the requirements of the process. The only way to determine the approximate carbon content, until its introduction, was to forge droplets from the converter. Göransson sent some of his steel to this country and it was successfully worked up into various products—a welcome contribution to morale, if nothing else, at a time when things were not going smoothly on the Bessemer home front. It would seem that, at this point, Bessemer, with Swedish iron as raw material, could make steel of varying qualities, but that the results were irregular. Göransson, without doubt, contributed the all-important 'know-how' of this control. There is evidence that in September, 1858, when Göransson visited London, Bessemer was granulating his blown metal, sorting it out into carbon qualities, and remelting it in crucibles—a practice which would remove many of the economic advantages of the process. An entry for 18th June, 1859, in the diary of W. D. Allen, Bessemer's brother-in-law, states: "First made steel direct." There is little doubt that this short entry epitomizes the important contribution which Göransson made to the development of the Bessemer process. But the success on Swedish methods and materials was a limited one: it was merely a confirmation that the process could, with certain not very widely available raw materials, make soft malleable iron or varying grades of steel.

Mushet's Contribution

The real problem was to make good malleable iron from British pig iron, even if low in phosphorus, made with what at that time was termed mineral fuel. There is no doubt that Mushet knew the answer to this before Bessemer did. Within a few weeks of the Cheltenham meeting, Mushet made iron ductile when hot from red-short blown metal by remelting it with spiegel. He applied for a patent on 22nd September, 1856, the complete specification being filed in March, 1857. During this time, Bessemer was in dire trouble looking frantically for cause and cure of both the defects in his product. It is known that, on hearing of Mushet's success, he visited him several times. Mushet, however, felt himself bound in honour to others—a great misfortune not only for Bessemer, but, as Mushet acknowledged later, for himself. So far as Bessemer was concerned, the failure to link their efforts led to a lost year or two and much anxiety and expense, but in Mushet's case he undoubtedly lost a wonderful opportunity of financial gain and a larger share of posterity's laurels than he has in fact received.

To say, however, that Mushet knew of the vital beneficial effect of manganese before Bessemer is not to say that Bessemer was necessarily directly indebted to Mushet for the ultimate success of the process. Bessemer himself claims that his attention was first directed to manganese as the key to his trouble by reading the supplement to Dr. Ure's "Dictionary of Arts, Manufactures and Mining." This described how Heath, many years before, had turned indifferent into good-quality iron by the use of manganese. Bessemer immediately commenced experiments. This must have been late in 1856 or early in 1857. He claims that these experiments with manganese were made about a month before any one of Mushet's patents was published or could be known to the world. As Mushet's successful addition of spiegel was only two weeks after the Cheltenham paper, it is certain that he was before Bessemer with a solution for eliminating red-shortness. Bessemer's complete story on manganese in steelmaking, however, certainly justifies his position that Mushet had no legal claim on him. Mushet's patent had been allowed to lapse and the use of manganese was already known in crucible steelmaking practice: Bessemer's position was that Mushet's patent had "pointed out to me some rights which I already possessed." It was with this in mind that, when asked, he came to Mushet's financial assistance, when that gentleman was in monetary difficulties: later, he paid him an annuity of £300. It is pleasing to note also, from the Institute's records, that Bessemer was a cordial supporter of the proposal to award Mushet the Bessemer Medal in 1876.

Ferromanganese Development

The limitation on the use of spiegel was soon realised: it was only in making higher-carbon products that it could be employed, and Bessemer later went so far as to say that some of the reports of unsatisfactory Bessemer steel which delayed its adoption for some purposes were due to its use. The low manganese/carbon ratio led to high carbon content in steels where a low carbon was desirable, e.g., in ship plates. The story of how Bessemer took active steps to obtain high manganese/carbon material, known to us today as ferromanganese, is one of the many interesting sidelights of metallurgical history with which he was associated.

Bessemer claimed repeatedly that, owing to pressure from friends, he had described his process when it was proven scientifically but not commercially. We have seen that the all-important step from the experimental results, described at Cheltenham, to commercial practicability took at least two years.

Whatever may have been the doubts and difficulties associated with the metallurgy of the process, there never was any question about the suitability of the plant which Bessemer designed for it. His mechanical genius had full scope and flowered prolifically: he not only developed the pneumatic idea, but he handed over a literally complete operating practice which has stood the test of time. There have been, naturally, variations in engineering techniques—electrical, hydraulic and mechanical—which have been applied to later operations, but in essentials the units at work today differ but little from those which Bessemer designed one hundred years ago.

Before describing the rapid expansion of the process subsequent to 1859, we can look with profit, I think, at the birth of the original idea and its growth. Bessemer wrote that the object he set himself: ". . . was to produce a metal having characteristics comparable with those of wrought iron or steel and yet capable of being run into a mould or ingot in a fluid condition." The first experiments in this direction were based on the general idea of dilution. Having fused pig iron in a coal-fired reverberatory furnace, he introduced bars of blister steel. The high temperature necessary for the

fusion of large proportions of steel in the bath was obtained by increasing the relative fire grate to hearth area, and by introducing additional air through openings in the fire bridge. He claims that some of the samples of metal which he produced were, after annealing, of extremely fine grain and great strength. There seems little doubt that had he continued with these experiments, what ten years later became known as the Siemens-Martin process would have been developed at that time.

Open Hearth Method Abandoned

The train of incidents by which Bessemer was deflected from his original open-hearth attack to pneumatic purification of the metal is by no means clear. Bessemer himself claims that in melting down pig iron in his reverberatory furnace what were apparently some pieces of iron were left on the bank and, even with increased air, remained *in situ*. Later still, having failed to melt them, he discovered that they were in fact shells of decarburized iron. This led him to infer that the end he had in view could be achieved by the use of air blast on hot metal. From this conclusion followed experiments in a crucible with a single tuyere, and these, in their turn, led to further experiments with what were in fact rudimentary forms of stationary converters. He finally succeeded in producing an ingot about 6 cwt. in weight and 10 in. square of purified iron which was malleable, and this, to use his own words, was ". . . the first born of the many thousands of the square ingots that now come into existence every day."

Bessemer's brother-in-law, W. D. Allen, gives a slightly different account of these early events during the interesting reminiscences with which he acknowledged the award to himself of the Bessemer Medal in 1890. According to his account, they had failed to melt some iron because of poor draught in the furnace. A small quantity was, however, melted at the bottom, and Bessemer suggested that " the nozzle be put in, to try and convert that which was melted." In a few minutes " the whole pig was in a beautiful fluid condition." Now the apparent contraditions in the recollections of two elderly gentlemen forty or more years later may not seem of very great importance, especially as in the event itself things could not very well have gone better, but there are two reasons why we must examine them. In the first place, as I suggested earlier, Bessemers' original idea was obviously to improve the strength of the iron mass by dilution with a stronger material: the process with which he finally finished up bears no relation whatever to this principle. Further, it is not clear, apart from the incident of the unfused shells, at what point he switched to the general principle of purification by oxidation. This may be an early illustration of the practice, still in vogue in many quarters, of providing a fortuitous empirical result with an appropriate theory, after the event. It would have been pleasing to suggest that purification by air blast with its wonderful directness and simplicity was characteristic of the Bessemer method of approach to any problem, as many of his earlier patents exhibited these features, but, in this, the most important invention of his life, there would seem to have been some element of luck in the way in which he stumbled on the fundamental principles and applied them to this process.

The second reason why this aspect is of some importance relates to what one might call the Kelly controversy. It is generally agreed now that Kelly, an iron-maker in the Southern States of America, was using an air blast to refine pig iron some six or seven years before Bessemer was even interested in ferrous metallurgy. Iron plates made by Kelly's ' air boiling ' process had been in use for some time, although the process ultimately had been abandoned. What Kelly did not achieve, in the first instance, was the liquefaction of the purified iron, and there is no doubt that it was only after he patented his air-blast method, subsequent to Bessemer's American patent, that he set out to get a liquid product. On the other hand, Bessemer's claim, at least for his American patent, excludes injecting streams of air for the purpose of refining iron, " that being a process known and used before." It would appear, from what little impartial evidence there is, that Kelly was concerned in the first instance with improving the method of making refined iron and malleable iron, whilst Bessemer's intention was to substitute a better ultimate product than that obtained by the puddling process. Bessemer's skill in engineering and plant design meant that, personally, he was able to develop practical apparatus for commercial production much earlier than Kelly and his associates, and had this field protected by patents.

Increased Operating Rates

It is at this point that another figure who made a major contribution to Bessemer practice comes upon the scene—Alexander Lyman Holley. A consulting engineer, already well established, he was sent to England in the early days of the American Civil War (1862) to study improved materials for armaments. He immediately acquired a licence for Bessemer's American patent and, on his return, proceeded to install a plant. In the meantime, the Kelly interests, with a strong patent position, made stronger by acquiring Mushet's American patent on the use of spiegel, were also going into production. After two to three years of patent dispute (neither party being able apparently, in the American patent tangle, to make steel without infringing the rights of the other), they came together in a fusion of interests, and the pneumatic process in America finally started production about 1866. Whatever may be the merits or demerits of Kelly's claims, it is significant that it has never been known by any other name in America than the Bessemer process : as Carnegie once remarked, no one doubted that " Bessemer invented Bessemer." From 1866 onwards, the development of the process was phenomenal, and the American practice rapidly achieved a pre-eminence in speed of working and output rates compared with those obtaining in Europe.

We have already seen that Bessemer had established all the essential mechanical plant items of his process, but the Americans, and particularly Holley, modified and improved these to secure high output and fast operating times—an early example of the beneficial results to be obtained from the study of what our American friends today have taught us to call ' logistics.'

The engineer who was chiefly responsible for these changes was Holley, and one is tempted to linger for a moment on the work and character of this fine man, who well deserves a place in our Bessemer Centenary Celebrations. He was an early example of that type of technologist, the need for which is being realised more and more today: his educational training embraced a degree in the humanities from Yale and an engineering apprenticeship in various spheres. He combined culture

and technical skill, while he was endowed with a quite unusual personal charm. Before his early death at the age of 50, he had made a major contribution to the introduction and development of Bessemer process engineering. The Bessemer Medal, recognizing these achievements, was awarded posthumously in 1882.

Problems Overcome

For the reasons just given, the process was already well established in Europe before the American practice matured, but this did not take place without hard work on the part of Bessemer and his friends. Following the solution of the problems set by the disasters experienced in 1856, the process had to be virtually re-introduced. Bessemer read a paper in May, 1859 to the Institution of Civil Engineers on the "Manufacture of Iron and Steel," and this represented the revised version of the Cheltenham paper, in so far as it brought matters up-to-date, and indicated that all was now in train for successful commercial production. It was a lucid statement of the advantages of the new method, and was obviously directed at a wide range of potential licencees.

It was not to be wondered at that the ironmasters, in view of their experience on the first attempt, were somewhat reluctant to take further risks, even although they did not lose the £27,000 they had paid for licences in 1856—Bessemer and his partners bought the rights back for, in all, £5,500 more than they had been paid for them. This comforting piece of capital appreciation, however, did not remove the incredulity engendered by the earlier debacle, and the resumption of the use of the process and the recruitment of new licencees was a slow business.

As far as the steelmakers were concerned, not one of the Sheffield companies would adopt the process unless on monopoly terms, which Bessemer was determined not to concede. He adopted 'war-into-the-enemy-camp' tactics and decided to build a steel works of his own in Sheffield. This he did, and, in addition to competing with the established Sheffield steelmakers in tool steels and similar products, the works made a large variety of products for various uses, with a view to demonstrating the applicability of Bessemer steel. The facilities the works provided for practical demonstration did much to accelerate the adoption of the process for steelmaking by others.

The quest for licencees was accompanied by an invasion of markets, not only those at that time sacrosanct to wrought iron but new markets for which the new material appeared to be particularly suited. A paper read to the Institution of Mechanical Engineers in 1861 and the International Exhibition of 1862, at which Bessemer had a comprehensive display of various manufactures made from his steel, showed that real progress was being made. It would be a mistake, however, to suppose that the replacement of wrought iron by steel was either automatic or rapid. In spite of advantages in cost of production and in many other directions, there was a considerable measure of resistance to the changeover.

Broadly speaking, the engineering world was divided into two factions; those who dared and those who did not.

Some, greatly daring, went so far as to be not only users of the product but financial backers of the process. The display at the International Exhibition of 1862 had so interested a group of Lancashire engineers in the financial possibilities of the process that they set out to purchase a share in the patent rights. Bessemer was quite ready to recover something of his earlier outlays, but would not consider any arrangement which did not leave him in complete control of the patents, so far as royalty rates and licences were concerned. In the end, after very short and amicable negotiations, he was paid £50,000 by ten members of the group for a quarter share in the proceeds of the invention. The fortunate investors, in the ensuing ten years, received something over £260,000. In these days, when the technique of take-over bids appears to consist of shuffling and reshuffling script, it might be of interest to record that at the dinner at which the bargain we are describing was made, each of the ten gentlemen concerned produced "... from the depth of his pocket a neat little roll of Bank of England notes to the value of £5,000." Yet another note on this felicitous event: the well-known portrait of Henry Bessemer by Lehmann which hangs in The Iron and Steel Institute Council room was commissioned by Mr. Platt, the leader of the group, and his friends, and presented to Lady Bessemer.

Rapid Adoption

Returning to the engineer users who dared—boilermakers, shipbuilders, and a reasonable number of engineers lined up with the railways in what, in all circumstances, was a rapid adoption of the material. Lancashire boilermakers were making boilers from plates of Bessemer steel in 1859, whilst shipbuilders commenced to use the material about 1863. The latter use was considerably encouraged by an early regulation of Lloyds that 20% less metal was required in ships built from steel than in those built from wrought iron. The confidence of the railways is best demonstrated when one remembers that the London and North Western Railway put down a Bessemer steelmaking plant for their own use at Crewe in 1869. There were, of course, many obvious reasons for their interest and enthusiasm: railways were expanding rapidly, rail wear was a major item in maintenance cost, and their demand for material was getting beyond the available puddled-iron capacity. Bessemer himself records that twenty-four days after reading the Cheltenham paper, he sent two ingots to Dowlais where they were rolled into rails. These, however, were an experiment in rolling only, and the first rails laid for trial purposes under service conditions were at Camden Goods Station in May, 1862. They gave a wonderful record of service when compared with wrought iron.

Lined up with the forces of reaction—those who did not dare—were both the War Office and the Admiralty. In the case of the War Office, many years were to pass before a single steel gun was made, whilst nineteen years after Bessemer's discovery the Chief Naval Architect of the Royal Navy read a paper to the Institution of Naval Architects explaining just why there were no steel ships in the British Navy, although his potential enemies across the Channel had, at that date, three steel ships.

It certainly seems ironical that the material which was developed primarily for ordnance should be in use by almost every country in the world for that purpose except its country of origin. It is no part of our business here to sit in judgment upon individuals, but, unquestionably, the trouble with the War Office had its origin in personal views and interests. Bessemer interviewed, without result, the then War Minister, Mr. Sidney Herbert, a fine type of English gentleman politician who

was probably well used to extraneous pressures : he was the not-unwilling spearpoint of Miss Florence Nightingale's attacks on the War Office and the Army Medical Services. However, in the case of Bessemer and his steel, he fell back on the time-worn practice of consulting his technical advisers. In this, both he and Bessemer were less than lucky. The official concerned was Superintendent of the Royal Gun Factory at Woolwich Arsenal. In the early days of Bessemer's experiments on steel development, the officer who filled this post became a Bessemer steel enthusiast and, in fact, was responsible for convincing Sir John Brown & Co. in Sheffield that they should install the Bessemer process : he himself made a similar recommendation with respect to Woolwich. Unfortunately, in 1859, just when Bessemer was out of his troubles and when he was commencing to make ordnance for other governments, the new occupant of this office was as antagonistic to Bessemer as his predecessor was favourable, and nothing more was heard at that time of the proposal to install the Bessemer plant at Woolwich. The British Government held out until force of example from abroad and the removal of the obstructionist from his post at Woolwich cleared the way for rational action. The moral of this story, if there is one—and this may be a challenge to some people in office today—is that there should be experts to advise Her Majesty's Ministers of the responsibility and disinterestedness of their experts. As a similar moral could be drawn from Bessemer's abortive relations with the Admiralty, there is perhaps no point today in elaborating the reasons for the delay in introducing steel for naval shipbuilding in the later years of the last century.

The growth of the steel industry all over the world was rapid, as the usefulness and the relative cheapness of the new material became known. In 1865 the Siemens process was discovered, and also made rapid strides. The year 1907 is perhaps in interesting one, as it was in that year that open-hearth production eclipsed that of the Bessemer process. The relative outputs of these two major processes is largely a result of available raw material and the existing techniques at any given time, or during any given period. It would certainly be rash, in view of recent developments in basic Bessemer practice, to suggest that the relative decline in total Bessemer-steel production, as distinct from acid Bessemer-steel production, is permanent. Meantime, whatever may happen in the future, nothing can rob Bessemer of the credit for introducing a new type of material : of showing how it could be made and, more important, how it could be used. He was the creator of a new age.

In the Birthday Honours List (*Continued from page* 242)

M.B.E. (*continued*)

D. G. Reavey, Dock Engineer Manager, John Brown and Co. (Clydebank), Ltd.
A. S. Roxburgh, J.P., Master of Works, Gourock Ropework Co., Ltd.
A. H. Selby, Production Manager, George W. King, Ltd.
A. Shaw, Battery Division Sales Manager, Crompton Parkinson, Ltd.
C. H. Shaw, Chief Cashier, Imperial Chemical Industries, Ltd., Middlesbrough.
A. Taylor, Chief Safety Engineer and Civil Defence Controller for Richard Thomas and Baldwins, Ltd.
R. E. Tugman, Safety Officer, Alkali Division, Imperial Chemical Industries, Ltd.
S. Watts, Manager, Plane Department, C. & J. Hampton, Ltd.

B.E.M.

E. Briers, Smith, Metropolitan-Cammell Carriage and Wagon Co., Ltd.
J. Burkett, Foreman Electrician, Brigham and Cowan, Ltd.
C. Burn, Apprentice Instructor, Marshall Richards Machine Co., Ltd.
A. H. J. Colenutt, Foreman Electrician, J. I. Thornycroft and Co., Ltd.
A. Desborough, Instrument Assembler, Painton and Co., Ltd.
W. E. Downes, Traffic Supervisor, Shell-Mex and B.P., Ltd., Fulham.
W. J. Dyment, Development Engineer, W. & F. Wills, Ltd.
W. A. Eaton, Head Foreman, Bullet-Proof and Armour Plate Shop, Hadfields, Ltd.
C. H. Humphries, Grinder, Experimental Department, Rotol, Ltd.
J. Irwin, Fitter, Sirocco Engineering Works, Davidson and Co., Ltd.
R. W. Jackson, Chargehand, Albright and Wilson, Ltd.
G. Olsen, Horizontal Borer, Dawson and Downie, Ltd.
G. G. Purvis, Inspection Foreman, Vickers-Armstrongs (Engineers), Ltd.
G. W. Richardson, Toolroom Inspector, Vickers-Armstrongs (Engineers), Ltd.
D. H. Smith, Foreman, Shell Refining and Marketing Co., Ltd.
W. Starr, Toolroom Foreman, Pulsometer Engineering Co., Ltd.

Novel Flame Hardening Application

The National Coal Board has approved the use of a special process to combat mining subsidence. To remove the danger of subsidence of the surface near coal fields, some means of support must be provided within underground workings. In areas which are of no further use, the workings are usually filled in with pit spoilage which is crushed, mixed into a slurry with water, and forced by compressed air through steel pipes into the workings. The aggregate forms into a concrete-like mass and is able to withstand a great amount of pressure. But, due to the extremely abrasive nature of the aggregate, the bore of the stowing pipes is subjected to a considerable amount of wear and the process becomes uneconomical. With a view to lengthening the life of the pipes, British Oxygen Gases, Ltd., have been experimenting on the internal hardening of a number of pipes by the use of their flame hardening process. The pipes have been subjected to field tests over a considerable period, and the results have proved very satisfactory. The National Coal Board has now placed a contract for the treatment of a large number of pipes by the new process.

Sand Mould Penetration Testing

II.—A Practical Comparison of the Effectiveness of Sand Compaction by Several Foundry Moulding Techniques

By D. H. Houseman, M.A., Ph.D.*

Department of Metallurgy, University of Cambridge

*The mercury penetration tester (Metallurgia, 1956, **53**, 21) has been used to compare the effectiveness of sand compaction round a simple pattern by hand, pneumatic, jolt-squeeze, and sand slinger ramming. The results show that, when a sand mix suited to each moulding method is used, the sand-slinger achieves the highest degree of ramming in practice—although this is lower than that achievable by especially careful and vigorous hand ramming—and the jolt-squeeze machine achieves the least high degree of ramming.*

Introduction

THERE are five main methods used in the production of sand moulds in modern foundries. These are hand ramming, pneumatic ramming, jolt ramming, squeeze ramming and sandslinger ramming.

Hand ramming consists in the ramming of successive small quantities of sand with a rammer of small surface area. The method has low capital costs, but the results achieved depend entirely upon the judgment of the moulder.

Pneumatic ramming utilizes an air-operated ram in place of the manual one. The ramming force is well-controlled, but the degree of ramming given to any area is determined by the moulder. The method is much quicker than hand ramming, but is not applicable to such a wide variety of work.

In jolt ramming, the whole of the pattern plate, moulding box and sand mix are mechanically jolted on an anvil, the inertia of the sand providing packing. Jolts may vary from one hundred to about eight hundred per minute, depending on the mass being jolted. This method gives uniform packing on horizontal pattern surfaces, but is less effective on vertical ones, the most dense compaction being obtained at the bottom, nearest to the pattern face, owing to the weight of overlying sand.

Squeeze ramming is achieved by the application of a steady hydraulic or pneumatic pressure uniformly across the whole sand surface. Pressures of 25–35 lb./sq. in. are usual, and transmit a fairly adequate degree of compression through a 3 or 4 in. depth of sand; beyond this the degree of packing falls markedly.

A combination of jolting and squeezing is commonly applied in practice; the jolting gives even packing at the bottom mould face and the softer upper parts are compacted by a subsequent squeeze, a fairly uniform hardness over a depth of 6–9 in. being thus obtained.

The sandslinger throws sand with uniform, high velocity into the moulding box and gives very even packing; the sand is well aerated and thus in a condition of high 'toughness'. Moulds up to at least 9 ft. in depth are successfully rammed by the sandslinger.[1]

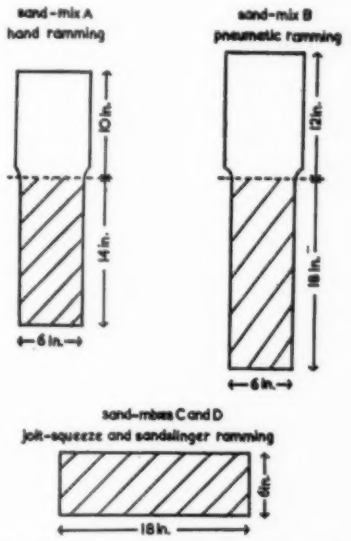

Fig. 1.—Diagramatic sketches of patterns used for making test moulds.

The technique of mercury penetration at room temperature, described in Part I of this series of papers, has been used to determine the degree of compaction achieved on the vertical mould surfaces formed by the patterns used for experimental 280-lb. and 360-lb. castings. A direct comparison has been made between moulds prepared by hand ramming, pneumatic ramming, jolt-squeeze ramming and the sandslinger. Fig. 1 shows diagrammatically the patterns used to make these moulds, samples being taken from the hatched area in each case. Sand mixes suited to each technique were used.

* Present address: Department of Metallurgy, University of Sheffield

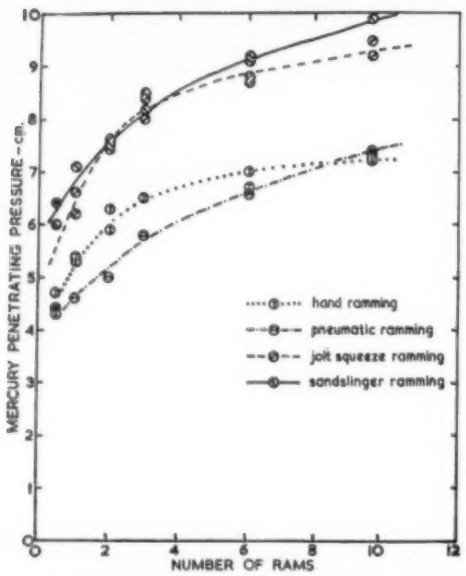

Fig. 2.—Penetration pressure v. degree of ramming curves for various methods of ramming.

Experimental Technique

Sand Mixes

Four sand mixes, A–D, were used, for moulds prepared by hand, pneumatic, jolt-squeeze and sandslinger ramming, respectively, as follows :—

Sand Mix A.	
Silica sand (Arnold's 52A)	92·6 wt. %
Quest bentonite	3·7 wt. %
Water	3·7 wt. %
Sand Mix B.	
Silica sand	92·5 wt. %
Quest bentonite	4·0 wt. %
Water	3·5 wt. %
Sand Mix C.	
Silica sand (King's Lynn Red)	57·2 wt. %
Reclaimed sand	37·5 wt. %
Wyoming bentonite	1·2 wt. %
Water	3·0 wt. %
Sand Mix D.	
Reclaimed sand	96·8 wt. %
North African bentonite	0·7 wt. %
Water	2·5 wt. %

The physical properties of the compacted mixes are given in Table I, together with some data obtained from the finished moulds.

TABLE I.—PHYSICAL PROPERTIES AND MOULDING DATA OF SAND MIXES.

Sand Mix	A	B	C	D
Physical Properties. (Tests on A.F.A. specimens compacted at 3 standard rams)				
Green Compressive Strength (lb./sq. in.)	4·3	3·3	7·05	9·25
Green Air-Permeability Number ..	530	380	240	195
Dry Compressive Strength (lb./sq. in.)	—	49	53	83
Shatter Index (%)	76	—	89	79
Moisture (wt. %)	3·4	3·5	3·0	2·35
Moulding Data				
Average Mould Hardness	—	90·4	89·8	85·0
Average Degree of Ramming over Surface Examined (standard rams)	3	3·4	2·8	4
Time to Produce Mould (minutes) ..	45	19	1·1	2

Results and Interpretation

Calibration Curves

By the use of standard-rammed compacts, a calibration curve of mercury penetration pressure *v.* degree of ramming was prepared for each of the four mixes ; these curves are plotted in Fig. 2.

Hand Ramming

A survey, made by means of the penetration tester, of two hand-rammed laboratory moulds showed that horizontal faces had hardnesses corresponding to the range 2 to 10 standard rams, whereas vertical faces were in the range $\frac{1}{2}$ to 3 standard rams. In order to confirm that this latter range was applicable to steel-foundry practice, a survey of ramming was made on one vertical face of the mould used for the 280-lb. casting mentioned above. The pattern size was $14 \times 6 \times 6$ in., surmounted by a $10 \times 7 \times 7$ in. head. The mould was carefully hand-rammed in an inverted position by a skilled moulder using sand mix A ; about 150 lb. of sand were used and the ramming occupied 45 minutes. Using the appropriate penetrating pressure *v.* degree of ramming curve in Fig. 2, the ramming survey of Fig. 3 was obtained. It will be seen that, although a high degree of mould ramming was achieved in the early stages, the hardness fell off, perhaps significantly, as the ramming proceeded. The degree of ramming over most of this face was in the range 1–3½ rams, the average for the whole face being 3 rams, thus confirming the laboratory observations.

When a casting in low-carbon steel was poured in the mould, general penetration of the face occurred when the ferrostatic head was such as would give penetration of the sand mix compacted to 1 standard ram.

Pneumatic Ramming

The pattern used in this test was $18 \times 6 \times 6$ in., surmounted by a $12 \times 7\frac{1}{4} \times 7\frac{1}{4}$ in. head, producing a casting of weight 360 lb. A special duralumin template, $18 \times 6 \times \frac{1}{16}$ in., having five rows of three $1\frac{1}{8}$ in. diameter holes spaced as in Fig. 4(*a*), was used in conjunction with this pattern. The template was pinned on to the face of the mould under investigation and penetration specimens taken by pushing the cork-borer through these holes in turn ; by this means the sampling positions in this and the two following moulds were standardized.

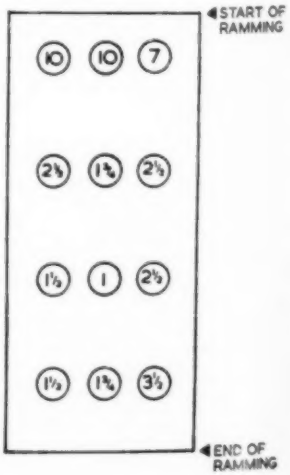

Fig. 3.—Ramming survey of hand-rammed mould.

The mould was carefully prepared, using sand mix B, by the moulder who had made the hand-rammed mould, using an air-operated ramming tool. This cut down the time for the production of the mould from *c.*45 to *c.*19 minutes (despite the somewhat increased size of the casting). When the pattern was stripped, a hardness survey was made of the face selected for investigation (that opposite the runner) as quickly as possible, in order to minimize the influence of mould drying-out on the results. The penetrating pressure samples were then collected at leisure, dried in the laboratory oven at 120° C., and the penetrating pressure values for mercury obtained. A set of standard-rammed samples of the same sand mix was used to determine the penetrating-pressure/degree-of-ramming curve shown in Fig. 2 and thus to obtain the ramming survey of the face shown in Fig. 4 (*a*) and (*b*). Again, great variations in hardness were observed over the face, the range being ½ to 9 standard rams and the average value 3·4 standard rams. From the four hardness readings about each penetrating pressure position, an average mould hardness for that

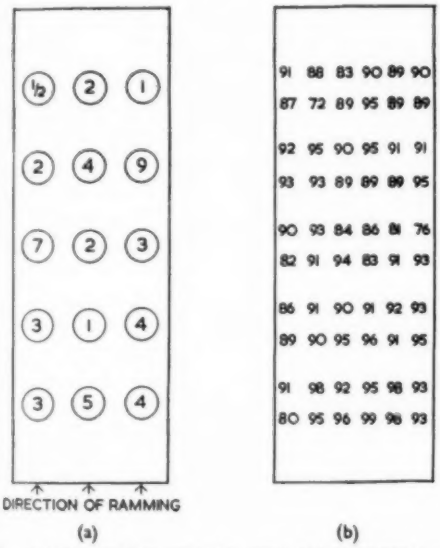

Fig. 4.—(a) Ramming survey, and (b) hardness survey of pneumatically-rammed mould.

region may be obtained. These values do not correlate well with the penetrating pressure values for mercury—in fact the correlation coefficient is 0·416; this, for 15 degrees of freedom, is significant only at the 10% level of probability.

Jolt-Squeeze Ramming

The pattern used for the pneumatic-ramming investigation was too tall to be used in machine moulding; the head was therefore removed and the pattern mounted horizontally on a pattern plate. Using a 9 in. deep moulding box (the pattern being 6 in. deep) the mould was made on an 800-lb. jolt-squeeze moulding machine, using sand mix C. The mould was jolted for 32 seconds and squeezed for 8 seconds before stripping, the total production time being thus little more than one minute. Despite this rapidity a very clear impression of the pattern was produced. As previously, hardness measurements were made immediately on removal of the pattern, and were followed by the removal of samples from a

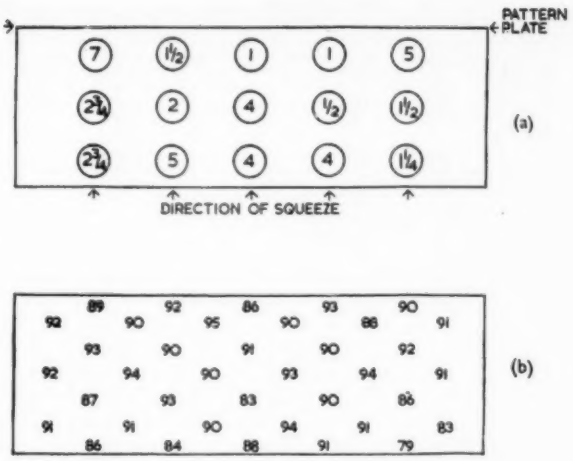

Fig. 5.—(a) Ramming survey, and (b) hardness survey of jolt-squeeze-rammed mould.

vertical face for penetrating pressure determination. Fig. 5(*a*) and (*b*) shows the result of this investigation. As indicated in Table I, the average degree of ramming over the whole face was equivalent to 2·8 standard rams, and the average indentation hardness 89·8.

Sandslinger Ramming

The pattern, still mounted on its plate, was transferred to the sandslinger bay and, with the same 9 in. deep moulding box, was carefully moulded using sand mix D. The time to fill the mould was 28 seconds, but it was necessary to turn the box over by crane before removing the pattern, so that the total time for this mould-producing operation was just 2 minutes. Again, a clear impression of the pattern was produced and no "patching" of the mould face was needed. Fig. 6 (*a*) and (*b*) shows the results of the ramming survey by penetration and by indentation tester, and mean values are given in Table I. This was a well-compacted mould (average degree of ramming equivalent to 4 standard rams); it should be noted that the reclaimed sand used contained a high proportion of naturally-bonded sand, thus ensuring excellent flow properties.

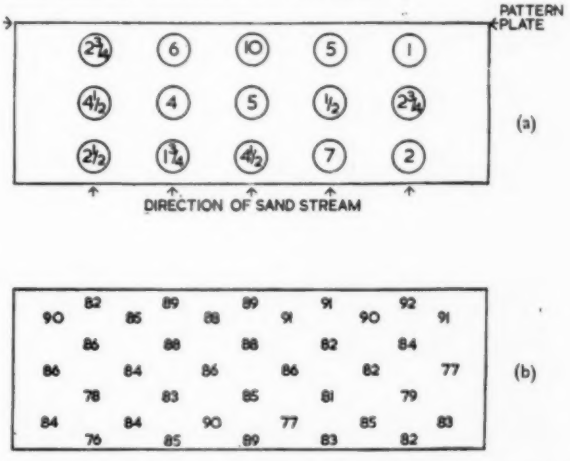

Fig. 6.—(a) Ramming survey, and (b) hardness survey of sandslinger-rammed mould

Discussion

Direct comparison of the results of these tests is complicated by the fact that each experiment had to be made using a different sand—though in each case that sand having moulding properties suited to the moulding technique in question was used. In every case a wide variation in ramming achieved over the face can be seen, though some general trends are noticeable.

The high degree of ramming achieved initially in the hand-rammed mould is noteworthy; actually the head had already been rammed before the moulder started on the pattern proper so that he had already been working hard for 15–20 minutes. It is thus perhaps not surprising that lower values were achieved during the second half of the ramming period.

The pneumatically-rammed mould does not show this trend. The ramming force does not depend on muscular power but on the degree of ramming, which is controlled by the time spent in ramming any particular area. The moulder simply shovels in a roughly constant amount of sand and rams this as he thinks fit. This technique results in layers of sand, each of high density at its rammed surface but less so the further one gets below the rammed surface. There is some evidence for this "layering" tendency in the penetrating pressure results obtained; it is not so readily observed from the hardness results, possibly because of the lower sensitivity of this latter test.

The jolt-squeeze technique uses a sand mix of high green strength and shatter index (i.e., a "tough" sand). High ramming values are achieved near the pattern plate (owing to the overlying sand) and far from the plate (owing to the transmisson-in-depth of the effects of the "squeeze"), but between the two a less-well-rammed layer occurs. The high figures obtained in the corners near the pattern plate are presumably related to the greater mass of sand being jolted there; the reverse is the case in the bottom row of ramming results—a pile of sand tends to be built up in the central part of the box, because that at the edge falls off during the jolting, and this central pile must be well compacted before the squeeze plate can come into contact with the sand more remote from the centre, and thus higher ramming and hardness values are found in the central parts of the mould

Sandslinger ramming gives a higher degree of compaction against the pattern plate (average *c.*4 standard rams) than does the jolt-squeeze, with lower compaction values further away from the plate, as might be expected owing to the good compaction of the lower sand layers obtained by means of the high-speed sand stream. Low indentation hardness values are found in this mould because an extremely flowable sand mix must, of necessity, be used with this technique. The dry strength of this sand mix is high (Table I), and high penetrating pressures were found in the dried specimens tested. Large moulds are produced by the sandslinger, and these are usually at least skin-dried prior to pouring.

We may thus conclude from this survey that, provided a sand mix suited to each technique is used, the sandslinger achieves the highest degree of ramming in practice—though lower than that achievable by careful and vigorous hand ramming—and the jolt-squeeze machine the least high degree of ramming. This order is, in general, also the order of casting weight, and thus also of the likelihood of high metallostatic pressures leading to penetration. The above results are for one type of jolt-squeeze machine only, used under particular conditions, and a wider survey might show different results; nevertheless the penetration that is sometimes found with small jolt-squeeze moulded castings (poured hot because of rapid solidification) may well be explicable by the limited compacting properties of the machine itself, rather than as a consequence of poor casting design or unsuitable sand mixes.

Acknowledgments

This work is part of a general programme on steel-casting defects that is being conducted under the direction of Dr. T. P. Hoar in the Department of Metallurgy, Cambridge University, with financial support from the British Steel Castings Research Association. I am greatly indebted to the Association and to its officers for their valued help and encouragement, and to Professor G. Wesley Austin for laboratory facilities. Thanks are also due to the Directors of K. & L. Steelfounders and Engineers, Ltd., Letchworth, for the provision of skilled moulding assistance, and for moulding materials.

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M.V. Apprentice Hostel

THE apprentice training facilities at Metropolitan-Vickers are very widely known, and for many years the majority of candidates for professional engineering training at the Trafford Park works have come from homes outside the Manchester area. Accommodation for these boys and young men has been found in lodgings in the vicinity of the works, and in general, this has proved a very satisfactory arrangement. There is, however, a great need to increase the number of candidates from public schools and grammar schools, and to facilitate this the Company has decided to build a new hostel that will provide accommodation initially for approximately two hundred.

An excellent site, known as Tyntesfield, has been found in Sale, Cheshire. Though across the county boundary, the hostel will be only four miles from the works and some seven miles from the centre of Manchester. The site is adjacent to the main Manchester to Chester road, thus affording convenient transport facilities to the works and the city, with ready access to the Cheshire countryside in the opposite direction. The hostel itself will be of modern design, and in its construction care will be taken to preserve the amenities of the well wooded site. It is hoped to have the hostel available for those who commence their training in September, 1958.

Nuclear Thickness Gauges Safe

As a result of a statement published by a German company to the effect that nuclear thickness gauges cause the materials used for food packaging (metal foil, paper, plastics) to become radioactive—the inference being that the nation's health would thereby be endangered—the Baldwin Instrument Co., Ltd., which manufactures this type of gauge, approached the United Kingdom Atomic Energy Authority. The Company states that the Authority denied categorically that the radiation source used in these instruments can impart radioactivity to other materials, or cause deterioration in the contents of the containers.

The Production of Thorium

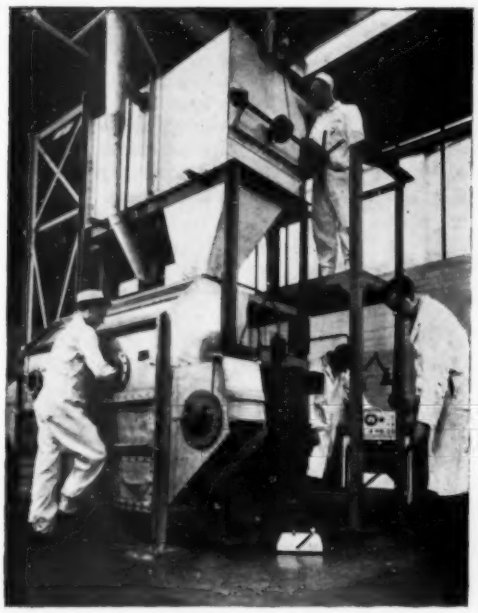
U.K.A.E.A. Factory Managed by Thos. Firth & John Brown Ltd.

IN 1947, at the request of the Atomic Energy Research Establishment, Harwell, then under the control of the Ministry of Supply, work was started in the Brown-Firth Research Laboratories on the development of a process suitable for the manufacture of metallic thorium. When a suitable method had been found, a factory was built in Sheffield which commenced operations on a production scale in January, 1950. This factory is now owned by the United Kingdom Atomic Energy Authority and is managed by Thos. Firth and John Brown, Ltd.

Thorium is capable of being converted to uranium 233 if it is placed in certain parts of an atomic pile. Uranium 233 is a fissile material with similar properties in this respect to plutonium and uranium 235. Naturally-occurring thorium cannot be used as the sole fuel for an atomic pile, as is the case with uranium, but thorium enriched with fissile material would be capable of such use.

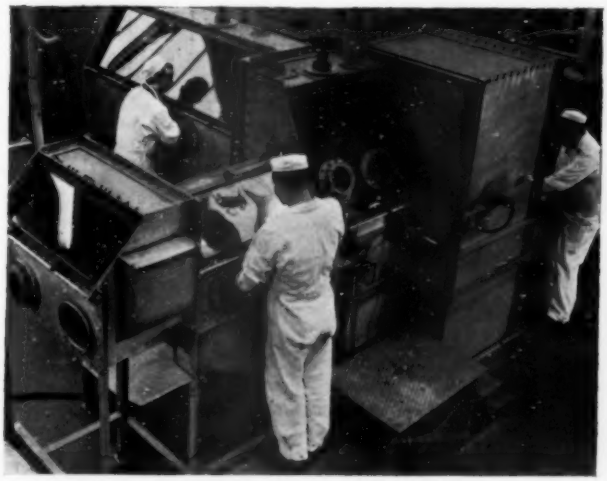
The raw material accepted by the Sheffield factory is thorium oxide, a material which has been used for many years in the manufacture of domestic gas mantles. The process used is basically as follows: thorium oxide is reduced to metallic thorium powder by the action of calcium. The thorium powder is separated from the other reaction products by a chemical process, and is then formed into shapes by pressure, and sintered at high temperature in vacuum furnaces. The now solid metallic thorium is then forged into forms suitable for insertion into atomic piles.

As with most materials used in atomic piles, the purity required is very high indeed. Certain impurities present to more than one or two parts per million will make the metal unusable. Thorium has a silvery appearance



A cabinet in which thorium oxide is being handled. Manual operations are carried out through gloved holes. Note the technician checking the radioactivity on the floor by means of a special geiger counter arrangement.

A part of the chemical separation plant.



A cabinet for handling thorium powder in which the powder is pressed into blocks.

when freshly machined, and is one and a half times heavier than steel. When pure, the metal is about as soft as copper.

In view of the radioactivity of thorium, special methods have been devised for carrying out the various processes involved, so that the plant operators are adequately protected from radiation hazards. These precautions also ensure that there is no danger of radioactive waste being accidentally discharged in the vicinity of the factory. Parts of the plant are shown in the accompanying photographs.

It is part of the general policy of the United Kingdom Atomic Energy Authority to supply certain materials of use in atomic energy to selected foreign countries. At the present time, thorium produced in the Sheffield factory is being supplied to France.

The Future for Metals and Metallurgists

Institution of Metallurgists Presidential Address

After briefly reviewing the progress of the Institution of Metallurgists, whose membership has risen from 1,250 in 1947 to 3,330 to-day, the new President, Mr. G. L. Bailey, C.B.E., spoke at the Annual General Meeting last month of the function of the Institution, before proceeding to a discussion of the future prospects for the use of metals, for metallurgists, and for the Institution. An abridged report of Mr. Bailey's address is presented here.

THERE is no doubt whatever that the Institution of Metallurgists is established and recognised. It is growing steadily and has succeeded in its aim of offering a professional qualification that is proving attractive. I should like, however, to address myself for a moment to the question of what use the Institution is to a man who has a professional qualification, particularly to a university graduate in metallurgy. What does such a graduate gain by continuing in membership of the Institution, with its regular annual subscription? Clearly the answer to the question is not obvious, because the majority of young graduates, who would be entitled to appy for Licentiateship after two years' satisfactory experience in metallurgical science or practice, or for the Associateship after they have attained the age of 25 and have had three years such experience, do not join the Institution. If the graduate compares the paper qualification of the Licentiateship or the Associateship with that of his Honours Degree, he may feel the Institution has nothing to offer him, but the Institution membership is not a paper qualification—it is an acceptance of a man on the basis of his knowledge and of his practical experience into the ranks of the profession.

Professor O'Neill spoke in his Presidential Address some years ago on two of the objects of the Institution, as set out in its Memorandum. I would like to refer to Paragraph 3*b* of the Memorandum, which reads as follows:—

> To promote in every possible way the interests of and to maintain and enhance the status and prestige of metallurgists and to encourage scientists whose main interests lie in metallurgy to become and to designate themselves "metallurgists."

This is, in my view, the basis of the Institution's work, and I would like to examine for a moment just what it means.

Metallurgy has been important as an art for many generations, but has only become established as a science during the present century. It has grown out of chemistry and physics, and its importance is becoming realised because of the vital part metallurgy plays in modern engineering developments. Professor Thompson said last year that, although the boundaries of metallurgy "may not always be very sharply defined, the scientific field of the metallurgist is sufficiently clearly outlined for the subject to be legitimately considered as a specific and distinct branch of knowledge." The realisation of the importance of metallurgy in engineering practice has not perhaps been accompanied by so rapid a realisation of the fact that the study of metals has become a science in itself, and that there is a growing body of scientists known as "metallurgists," whose efforts are devoted to the solution of these problems and whose work, both scientific and in the practical application of their results, is in every respect comparable with that of other scientists. I deplore the tendency fostered in some quarters to regard the physicist or the chemist working on the fringes of the subject as the real "scientists" in this field, although I would not for one moment belittle the value of the work they do.

The Institution's main function is to secure recognition of the metallurgist, be he working in the scientific or the practical field, and to ensure that his views command the same consideration when professional matters are under discussion in Parliament, by Educational Authorities or in the Press, as do the views of members of other scientific professions.

It seems surely superfluous to add that any measure of success in attaining this objective by the Institution must reflect favourably on the individual member. By virtue of his membership he is proclaimed not only as qualified, but as experienced, and to be trusted for the honesty of his opinions. The more successful the Institution is in recruiting members, the more powerful do its efforts become. Provided, therefore, the standard of entry is maintained, the further growth of the Institution is important to existing members because it improves its ability to serve them.

The futures of the Institution and of the profession are interdependent. The future of the profession in itself depends on the future of the use of metals, and I would like, therefore, in the rest of the time available to look at the question of the future prospects for the use of metals, for the metallurgist, and for the Institution.

The Future of Metallurgy

The vast majority of metals are used for traditional purposes which are neither spectacular nor particularly

exciting. The ordinary materials of construction, which have been so familiar to us since childhood, don't often excite the question "What should we do if we did not have, for example, steel, copper or cast iron?" There have, of course, been times, especially during the War, when this question had to be faced, and it was in many cases surprisingly difficult to find some other way of making relatively simple articles for which metals could no longer be spared. There are, of course, people who say that in years to come the world's resources of many of the common metals will all be used up. Granted these resources are not indefinite, the amounts do in a few cases seem virtually so. If and when the demand for specific metals exceeds the supply, the first thing that will happen will be a change in what is deplorably known as "the pattern of use." This can work in two directions, firstly the use of more readily available metals, such as aluminium, magnesium and maybe titanium, for purposes for which the older metals have formerly been used, and secondly the increasing use of non-metallic materials, such as plastics, for particular purposes previously fulfilled by metal. These are matters of economics and technical efficiency—if a plastic pipe has advantages over a metal pipe at the same price it will be used. If it is not so good, but is a lot cheaper, it will still be used to some extent, and it is in this and all other applications that the balance of use is always going to be changing as new properties are developed in materials, and as new methods of production are developed which vary the price ratios.

It is this factor (new methods of production) that is of basic importance. When one sees estimates of known world resources, one firstly has to remember that detailed prospecting of an ore body is usually carried out only so far as to ensure that demands for a specific and limited term of years can be satisfied, and secondly that what is not an ore body to-day might well become an ore body tomorrow, by some change in price or, particularly, by some development in beneficiation or in smelting processes which enables a poorer material to be used more efficiently. For instance, aluminium is to-day produced from bauxite, of which there is quite a lot in the world, but there are immense amounts of aluminium in clays richer in iron which can be used, although with present knowledge at a higher cost. Considerations of this sort make it difficult to forecast what is going to happen regarding the use of particular metals in the distant future with the assurance that some people less concerned with the industry have adopted.

Apart from these traditional uses, there are more interesting and spectacular uses of metals which control the whole future of development in many fields of engineering. The problems of high speed flight and the development of nuclear power depend almost entirely on the development of metals which will withstand the conditions the engineer wants to meet. It is yet to be seen how far alloys based on the newer metals can be made with properties which we have not hitherto been able to attain, and this opens a vast new field for metallurgical endeavour which seems to me unlimited.

The big competitor with metals in mass-production uses is likely to be plastics which, when suitably reinforced, can provide a valuable and a strong material for many purposes. The plastic car body, for example, and the plastic boat hull are known. Plastics are relatively young and are being developed and improved enormously and there is an assumption in some quarters that they will go on getting better and better and cheaper and cheaper while metals are becoming "in short supply." I don't see this at all—given sufficient energy, imagination and enthusiasm on the part of the metallurgist, metals can also get better and cheaper by improving methods of extraction and fabrication, and by developing new alloys with better properties. My forecast is that the future of the use of metals for traditional purposes, and for the smaller, but nevertheless more spectacular, purposes of modern engineering is not only assured but is extremely interesting and in places exciting.

The Metallurgist of the Future

The difficulty in all this is the immense field which the subject of metallurgy covers. Extraction is a combination of chemistry and physics applied to metallurgical processes, but predominantly requires a knowledge of chemistry, especially in the modern wet processes. The study of alloy structures and behaviour is essentially based on physics, but physics highly developed and specialised in particular directions, and closely associated with physical chemistry of a highly advanced nature. Electroplating is a combination of chemistry, particularly physical chemistry, and electrical engineering, and so on through the melting, casting, heat treatment, mechanical properties and the many other aspects of metallurgy which are being, and must be, studied. The basic science may be that of one of the older disciplines (as it is in fact in medicine, and particularly in physiology), but the pure scientist trained in those disciplines cannot play his part effectively in metallurgy unless he allies his basic science with a general knowledge and a practical appreciation of the extraction, fabrication and use of metals. The physicist may and does do invaluable work for the metallurgist in the field of the physics of the solid state, but he does not for that reason alone become a metallurgist, entitled so to call himself or competent to deal with the varied aspects of the behaviour of metals which must be understood if they are to be used in practice in a proper and sensible way.

As in all branches of science, intellectual honesty is the first and most basic consideration. It follows particularly from what I have said earlier that in the future there will be plenty of room for all materials—metallic and non-metallic. Choice will increasingly be made on the basis of detached judgment. It is all the more important that the metallurgist can be relied on to maintain that strict level of professional integrity that will retain the confidence of the public. Membership of the Institution provides a guarantee in this respect, and it is important that this situation be maintained.

There is no doubt the metallurgist must specialise—no one man can be an authority on smelting and extraction, gas metal reactions, mechanical deformation, and electroplating, to name just a few examples. What sort of training, therefore, are we intending to give to people working in this field? In the first place, I think it important that the basic school education should be broad. The Institution co-operated with other metallurgical institutes on the Joint Committee on Metallurgical Education which some years ago prepared a report on the requirements for university entrance in metallurgy. In this, we recommended that the standard of entrance should be lowered in science subjects in order to make provision for the requirements of a deeper

knowledge of the English language and the humanities. That report, I fear, fell on deaf ears, but I will stand by it and deplore the tendency to excessive specialisation in science in the later years at school in order to gain university entrance. Secondly, whatever branch of metallurgy a man is going to follow he should have a training in chemistry, physics and mathematics to a high level.

I think the university graduate of to-day gets sufficient training in those basic sciences, but I do think it is a real weakness of our Institution examinations (and of the exemptions agreed for anything other than a university degree) that we are giving too much training in metallurgy with too little basic understanding of the pure sciences on which it is based. I would earnestly commend to the Council the importance of considering the specification of a higher level of basic science training for Licentiates and Associates. It is difficult to see at first sight how this should be done. I think there is a lot to be said for regarding metallurgy as a course of study to follow an advanced training in the basic sciences, as for instance in the Cambridge course, where the natural sciences at degree level precede a year's intensive training in metallurgy. I should like to see a Higher National Certificate in Chemistry, Physics and Mathematics, if there were such a thing, preceding the two years' Higher National training in metallurgy, with, if necessary, a reduction in the amount of purely metallurgical knowledge that the student acquires. Without this I realise one could go on making the courses longer and longer. I do not think the standard of basic science in the Ordinary National Certificate, which is all that is possible at present, is adequate.

When studying metallurgical subjects in his undergraduate or technical college training, the metallurgist should be provided with a ground work to the whole subject, rather than specialise in part. Specialisation must come after the basic training, and can largely be achieved in industry. Industry is increasingly recognising that " post-graduate " training, using this term in its widest sense, is an important step for men intending to take charge of works' operations, and I would only plead with the metallurgist himself to realise it too, and not to assume that because he has such and such qualification that he is " qualified." That is where the Institution's qualification is so important. It is not skill in passing examinations alone that can admit a man to the Institution, but he must have some years of experience in using that knowledge, and only when he has that experience is he regarded as fully qualified.

The Future of the Institution

We then come to the last question on which I would only say if you are with me in believing that metals are going to continue as a most important and basic factor in the development of our civilisation ; if you are with me in believing that this will require a constant exercise of ingenuity in developing materials with the right properties, using them in the right way, and taking advantage of all the newer alloys and processes that come along ; you will not have any doubt that the metallurgist, important though he is to-day, is going to get increasingly important in the future. He is in fact going to be one of the key men in engineering development.

There can, in my view, only be any question that in such a situation the Institution would be required to maintain the standard and look after the interests of the profession, if there is something different about our profession in this respect than there is about any other. I cannot see that difference, and to me, therefore, the need for an Institution is not in question. We must, however, look at the efficiency with which our own Institution will have to do its job if it is going to justify its existence.

On this point I must remind you platitudinously that you are the Institution—that it has no existence apart from its members, and that if its potential members stay outside and watch the Institution's activities in a detached sort of way, prepared to criticise but not prepared to help, it will not get very far. On the other hand, if metallurgists are going to see to it that their Institution is efficiently run and does do its job properly, they must provide the central organisation with the tools with which to work. It is no good criticising the Council of the Institution if they cannot afford to employ competent staff, and it is no use criticising the staff if they are overworked and cannot afford the junior assistance necessary to enable them to function efficiently.

We are, in the Council, doing our best to provide Dr. Merriman with the assistance that he needs. We are not paying too much attention to whether we can afford it, because we believe that we must do the job properly or go " bust " in the attempt. If, therefore, the members of the profession who are members of the Institution, and those who are not, want to see this job done properly, all I ask is that they give Council the support that the members alone can provide.

A Novel Continuous Pusher Furnace

WHAT is claimed to be the most significant change in mill furnace design in the post-war years is that embodied in the Thermo furnace, designed for medium and large outputs. The salient aim in developing the furnace was to produce in every case the ideal thermal treatment for steels prior to rolling, whatever their constitution, and by providing positive zoning, the temperature and furnace atmosphere in each zone are capable of the precise control required for this purpose. Refractory skids of a high degree of durability form a very important part of the design, as does the instrumentation necessary for such precise control.

The Thermo furnace was developed over a period of three years by The Thermo Industrieofenbau G.m.b.H., a subsidiary company of " Ofu " Ofenbau-Union G.m.b.H., Düsseldorf. This development took place first in Austria, then in Germany, and several installations have already proved the validity of the claims which are made. The licence to manufacture and sell mill furnaces to this design in Britain and the Commonwealth has been granted to Gibbons Brothers Ltd. of Dudley.

Vicker's Australian Company

VICKERS have formed a company in Melbourne, Australia, under the name of Vickers Australia Pty., Ltd., to take over their Australian investments, viz., in Cockatoo Docks & Engineering Co. Pty., Ltd., Vickers Ruwolt Pty., Ltd., and Vickers-Armstrongs (Australia) Pty., Ltd. The acquisition of a 75% interest in Hoskins Engineering & Foundry Pty., Ltd., Perth, recently announced will be carried out by the new company.

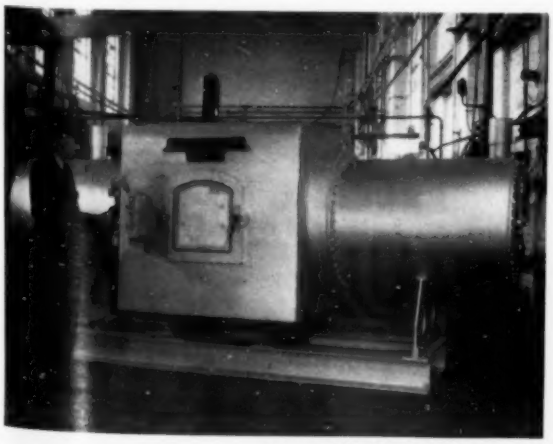
Recent Heat Treatment Furnace Installations

A Review with Some Typical Examples

Progress in the design and construction of heat treatment furnace equipment continues on a considerable scale, and furnaces and equipment of a very high order have been installed during the past year. Developments have largely centred on the demand for continuous heat treatment processes, but semi-continuous and batch type furnaces are being increasingly installed for more general work. Although necessarily incomplete, the present review indicates, with typical examples, the general trend of progress in this field.

IN the broadest sense, the term heat treatment embraces almost all the processes involved in converting ore into finished metal products, but in this review more particular attention is directed to equipment in which the heat treatment operations are designed to modify the form, structure, and constitution of the metal by controlling the heating and cooling conditions under which changes in the solid state occur. It has long been appreciated that control is not only concerned with the use of modern appliances developed to assist in maintaining a uniform temperature in the furnace chamber, but in controlling the time and rate of heating and cooling, and the atmosphere surrounding the material undergoing treatment.

In making a choice of heat treatment plant, it is important to make a careful assessment of the many factors involved. While the particular conditions at the works where the installation is contemplated have an important influence, the guiding principles should be mainly concerned with reliability, flexibility of output, and ease of control, the quality of the finished product and its overall cost being primary considerations. For mass production, the duty demanded of heat treatment furnace units may, and frequently does, amount to a very precise and clearly defined treatment and output. The allowable margin to cover contingencies and unknown factors is much reduced in furnaces specially designed for the treatment of particular products, but a fair measure of flexibility of output and range of temperature is demanded in many types of general purpose heat treatment plant.



Courtesy of The Incandescent Heat Co., Ltd.

Fig. 1.—A town's gas-fired furnace, operating on a regenerative system, designed for temperatures in excess of 2,000° C. without oxygen enrichment.

Courtesy of G.W.B. Furnaces, Ltd.

Fig. 2.—Work coil of a mercury-arc, medium-frequency induction heating furnace.

In recent years, the trend of furnace design has been mainly concerned with the simplification of operation. All modern furnaces are equipped with automatic temperature control, and where the process makes it necessary, automatic heating cycle control. In some operations, the constitution of the atmosphere in contact with the work undergoing treatment is important, and it is noteworthy that facilities have now been developed for controlling the carbon content of the atmosphere for such purposes as carburising and carbonitriding. These controls enable uniform results to be obtained, such as will meet the exacting demands of present day metallurgy, without requiring a large staff of skilled men to carry out the work. In effect, heat treatment furnaces are increasingly becoming precision instruments. To meet the requirements of modern production methods, mechanical handling equipment, to facilitate the various operations, is now generally employed, and there is ample evidence of considerable progress in this direction.

In a previous review reference was made to the development of a high temperature furnace, operating

Courtesy of The Incandescent Heat Co., Ltd.

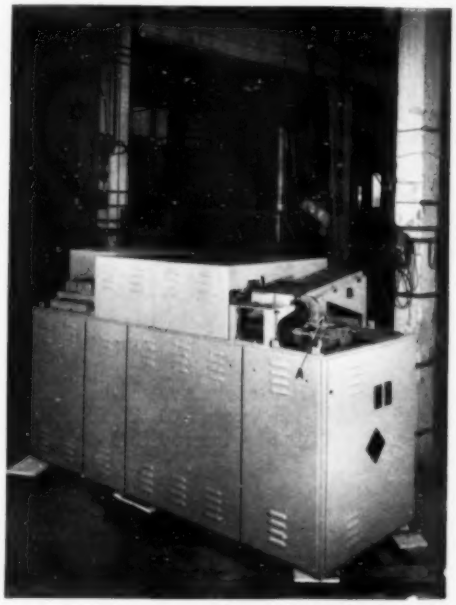
Fig. 3.—A forge furnace incorporating the Equiverse system.

on ordinary town's gas, in which a temperature in excess of 2,000° C. was reached without oxygen enrichment. Fig. 1 shows such a furnace, which has been installed by a large engineering firm for experimental and research work; the heating chamber is 18 × 18 × 18 in.

Reheating

Although furnaces are more generally used for reheating cold stock, preparatory to subsequent operations, heating by induction is making rapid progress in this field. An important development in the application of medium-frequency induction heating has been achieved by the use of mercury-arc invertors for frequency conversion. G.W.B. Furnaces, Ltd., and The English Electric Co., Ltd., have co-operated on the technical aspects of this development, and Fig. 2 shows the working part of a unit used for heating steel bottle ends, prior to hot forming and reduction to the required end shape. Many advantages are claimed for this type of equipment, including fast heating-up times, resulting in reduction of scale; and high efficiency, since heat is generated in the workpiece itself—power being produced by the rectifier only when actually required.

A more conventional method of reheating stock for forging purposes is by means of the furnace shown in Fig. 3. This forge furnace incorporates the Equiverse system, which enables the furnace to heat steel rapidly to forging temperatures without forming scale. The furnace illustrated is capable of dealing with 1,080 lb./hr. of steel. Billets heated to a temperature of 1,280° C., and subsequently allowed to cool in a nitrogen atmosphere, showed no sign of oxidation. This is effected by a new system of atmosphere control by which the carbon monoxide content is maintained between 12 and 16·5%, in which atmosphere scale formation on heated steel billets drops to practically zero. In addition to scale-free heating at temperatures up to 1,300° C., improved heating rates and fuel economy have been achieved by this development. Apart from several incidental improvements, the basis of the achievement is in the application of a pair of metallic matrix regenerators which will be noted above the furnace. Whilst the regenerative principle is used, the specially designed thermal pulsators exceed by many times the thermal rate of exchange obtainable in ordinary regenerative practice.



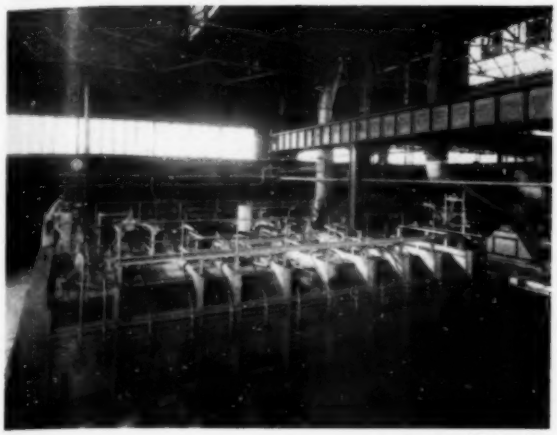
Courtesy of Electric Furnace Co., Ltd.

Fig. 5.—A dual-frequency billet heater having a single-phase normal-frequency coil for preheating steel billets to about 650° C., and a high-frequency coil for raising the temperature to 1,200° C.

Courtesy of G.W.B. Furnaces, Ltd.

Fig. 4.—Two twin-track electric resistance walking beam furnaces for heating brass slabs.

The twin walking beam furnaces shown in Fig. 4 have been supplied to a Royal Ordnance Factory; they are similar in design to a furnace previously supplied to the Metals Division of Imperial Chemical Industries, Ltd. The furnaces illustrated are of the electric-resistance



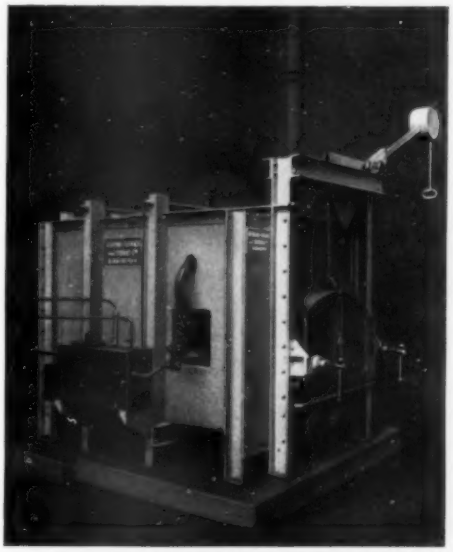
Courtesy of Birlec, Ltd.

Fig. 6.—An electric furnace installation for preheating light alloy slabs for hot rolling.

type, each rated at 1,380 kW., in five independent automatically controlled zones. An output of 9·2 tons/hr. of 70 : 30 brass slabs is obtained from each furnace, the slabs being preheated for rolling ; they are discharged from the furnaces from either side, as required by the rolling mill. A protective atmosphere, derived from burnt town's gas supplied through a G.W.B. exothermic atmosphere plant, ensures that oxidation of the slabs is reduced to a minimum.

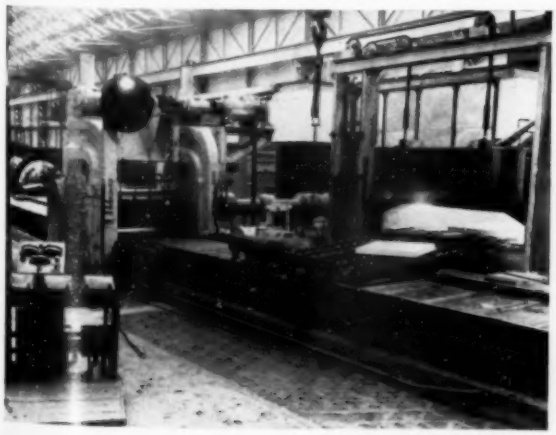
In the review last year, reference was made to an aluminium billet reheating furnace supplied to High Duty Alloys, Ltd., and operated on a balanced load from the three-phase supply at normal frequency. A more recent development is that shown in Fig. 5. This is a dual frequency billet heater, constructed by Société Générale d'Applications Electro-Thermiques to the design of Electric Furnace Co., Ltd. Three such units have been supplied, each having a single-phase normal-frequency coil to preheat steel billets to about 650° C., and a high (1,000 c./s.) frequency coil to raise the temperature to 1,200° C. The billets, 3·75 in. diameter × 8½ in. long, weigh 26 lb. each, and the three units have a combined output of 150 billets/hr. The total loading is 800 kVA., of which 500 kVA. is converted to high frequency. The billets are loaded on to the inclined chute *B*, and are charged at regular intervals into the inductor coil by the hydraulic charger *A*. The cold billet pushes out a hot one on to live rolls at the discharge end. The object of the use of dual frequency is to save in capital cost over an all-high-frequency heater, the billets being too small in diameter to be heated efficiently to forging temperature using normal-frequency current only.

An interesting installation for preheating light alloy slabs for hot rolling at the rate of 3 tons/hr. is noteworthy because of the highly mechanised handling of the slabs. The furnace, shown in Fig. 6, is electrically heated, with a total rating of 750 kW., divided into six separately controlled zones, and is designed to handle slabs up to 7 ft. × 3 ft. × 8 in., each weighing just over one ton. Powerful air circulation is employed to ensure rapid and uniform heating. The slabs are supported in an upright position on special alloy shoes, which are moved through the furnace by pusher mechanism at the loading end. At the discharge end, the shoes and slabs are extracted automatically from the furnace and the slabs transferred to the horizontal position on the mill table by a hydraulic mechanism. The shoes are then returned to the loading end by a conveyor at the side of the furnace. The furnace doors are opened and closed automatically, in conjunction with the operation of the loading pusher and discharge mechanism.



Courtesy of Modern Furnaces & Stoves, Ltd.

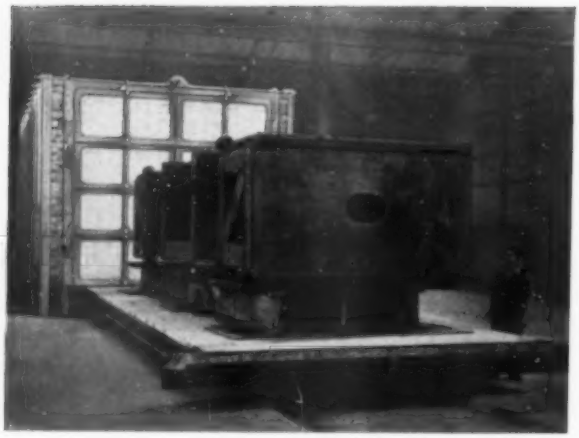
Fig. 8.—A billet heating furnace fired with fuel oil.



Courtesy of John Mathison, Ltd.

Fig. 7.—A copper slab reheating furnace fired by town's gas. Note the arrangement for feeding the mill.

The reheating furnace shown in Fig. 7 has been installed at the Elswick Works of Vickers-Armstrong (Engineers), Ltd. This furnace is on two-zone control, and is used for heating copper slabs, feeding them by means of electro-hydraulic pusher gear to a continuous sheet mill. The heating, which is by town's gas, is designed to give relatively high efficiency and uniformity when operating at about 6 tons/hr. continuously. The average gas consumption is about 2,000 cu. ft./ton of slabs reheated.



Courtesy of Modern Furnaces & Stoves, Ltd.

Fig. 9.—An oil-fired stress relieving furnace operating on the Newstad recirculation system

An oil-fired billet heating furnace is shown in Fig. 8. It has a working space 3 ft. × 4 ft. deep × 1 ft. 6 in. high. The unit includes control tanks and immersion heaters to preheat the oil fuel for combustion, the burners used being suitable for all types of oil fuel. By controlling the air valve, the burner adjusts the oil flow through suction caused by a vortex in the burner, without the operator having continually to adjust the air and oil together; a further advantage is that if the air supply should fail for any reason, the oil supply is automatically stopped.

In a walking beam furnace installed by Gibbons Brothers, Ltd., for heating brass and copper billets, truly rectilinear motion of the beam is achieved by having separate motors for the horizontal and vertical motions. The furnace is 5 ft. wide × 55 ft. long, and is fired by town's gas, using the Gibbons-Webb roof combustion system. Temperature is subject to control by a three-zone floating and proportional system, and furnace pressure is also controlled. The designed rate for heating billets to 800–850° C. is 7½ tons/hr. The extraction of the billets from the furnace is achieved by a peel type extraction gear operated directly from the main walking beam mechanism, and this is interlocked with the electrically operated discharge door.

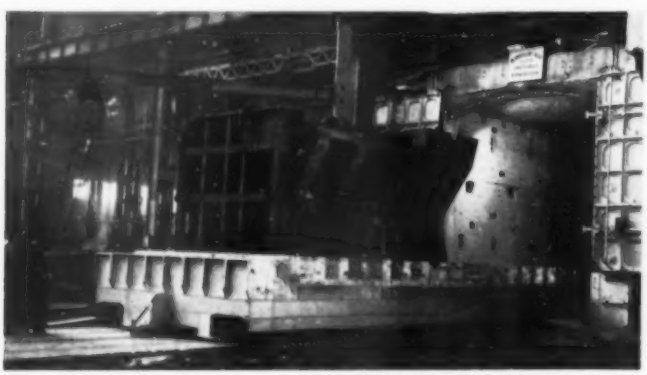
A British Furnaces rotary hearth furnace having an effective diameter of 7 ft. has recently been installed for the reheating of alloy forgings to 1,100° C. to give semi-continuous rolling of turbine blades. The combination of this type of furnace with alloy hearth and various labour saving devices has resulted in a larger and more uniform output from the mill.

Stress Relieving Furnaces

Considerable attention is now given to the need for removing stresses from fabricated structures. In many manufacturing processes, where heat is applied locally, residual stresses are set up and heat treatment to relieve these stresses is usually necessary. This is particularly true of welded components used in chemical engineering, which are liable in service to stress corrosion, cracking, or embrittlement at the weld. Residual stresses are also set up in castings, either as a result of unequal cooling, or due to the complexity of design.

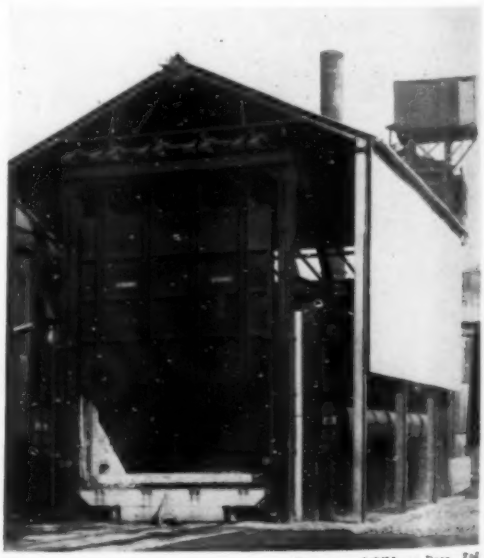
In special cases, unusual methods for stress relieving structures are necessary, and in an earlier issue of this journal reference was made to a large transportable furnace for this work, designed and built by Dowson & Mason, Ltd., and also the use of induction heating for relieving stresses in large welded heat exchangers adopted by the Electric Furnace Co., Ltd. Such cases are exceptional; the normal precedure is to carry out the treatment in a batch furnace, several of which have recently been installed for this purpose.

As is generally recognised with stress relieving furnaces, it is important that a uniform temperature should be obtained throughout the load, without any hot spots which may cause the load to exceed the maximum temperature. To obtain these conditions, the furnace shown in Fig. 9 has been so arranged that the oil burning equipment fires into separate combustion chambers, away from the actual work chamber, and the hot products of combustion, mixed with recirculated gases at controlled temperatures, are blown into the heating chamber at various points. In this way, flame impinge-



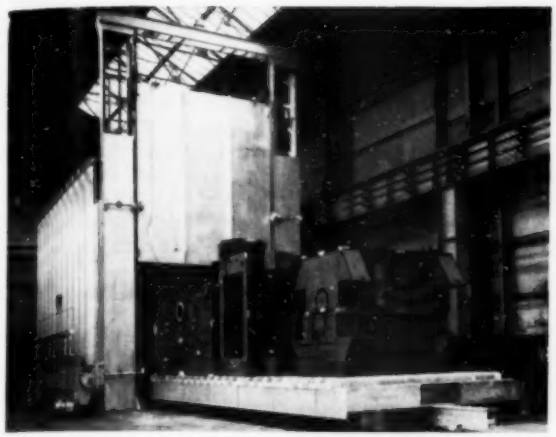
Courtesy of The Incandescent Heat Co., Ltd.

Fig. 10.—This stress relieving furnace is fitted with the Laclede-Christy flat suspended arch.



Courtesy of Gibbons Bros., Ltd.

Fig. 11.—Fired by raw producer gas, this furnace has been installed for the treatment of steel castings.



Courtesy of John Mathison, Ltd.

Fig. 12.—A six-zone, gas-fired, reciprocating type, stress relieving furnace, with a capacity up to 120 tons.

Courtesy of Birlec, Ltd.

Fig. 13.—An electrically heated furnace for bright annealing copper wire ; it has two separately controlled zones with a total rating of 170 kW.

ment and radiation effects from the burners are prevented, the complete heating cycle being maintained by hot gases only, and under strict thermostatic control. The furnace illustrated is 30 ft. long × 12 ft. wide × 12 ft. high above the bogie top, which is shown carrying a 40-ton weldment.

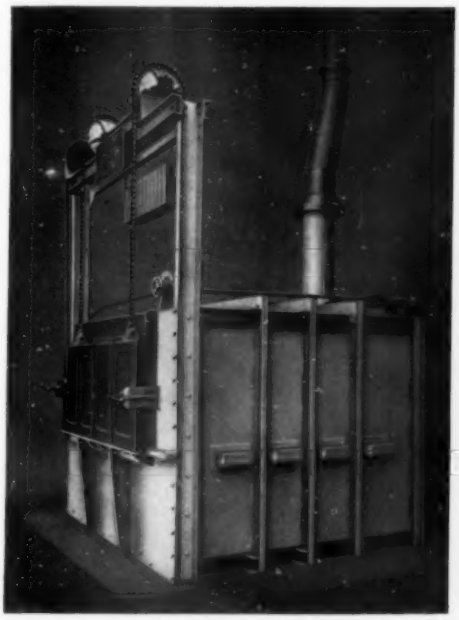
Another bogie hearth type of stress relieving furnace, recently installed at the Birkenhead Works of Cammell Laird & Co., Ltd., is shown in Fig. 10. This unit is 31 ft. long × 16 ft. wide × 16 ft. high, and was specially designed for dealing with welded structures. It is noteworthy that this furnace is fitted with the Lacelede-Christy flat suspended arch, which facilitates the construction of a furnace of these dimensions.

Raw producer gas is used to fire the furnace shown in Fig. 11, the heating chamber in this instance being 25 ft. long × 14 ft. wide × 8 ft. 6 in. high. This furnace is fired by the Gibbons-Webb roof combustion system, and is capable of dealing with a load of castings up to 100 tons in weight.

The six-zone, gas-fired, recirculating type, stress relieving furnace shown in Fig. 12, and recently installed at the Elswick Works of Vickers-Armstrongs (Engineers), Ltd., is capable of treating loads up to 120 tons. Its working dimensions are 35 ft. 8 in. long × 15 ft. 6 in. wide × 21 ft. high from bogie hearth level to crown. It is equipped with a six-point recorder and six indicating controllers, the gas and preheated air supply to each zone being automatically controlled by means of a motorised torque unit operating from the appropriate indicating controller. The furnace is designed to eliminate flame impingement on the materials being treated, and permits maximum heat transference whilst retaining the minimum temperature differential between the stock and the furnace atmosphere.

Annealing and Normalising Furnaces

A considerable number of annealing furnaces have been installed during the past year, one of the most recent being an electrically heated furnace for bright annealing copper wire installed at the works of Enfield Cables, Ltd. Fig. 13 illustrates the prototype unit for this type of furnace, which possesses a number of interesting features. The wire to be treated is wound on steel spools or drums up to 28 in. diameter, with a maximum of about 1,500 lb. of wire on each drum. With this size of drum, the furnace will anneal about 1¼ tons/hr. of copper wire at a temperature of 500° C., oxidation being prevented by the use of an atmosphere produced from an I.C.I. regenerative type of ammonia burner. The wire drums are carried on trays moving along two parallel rail tracks through the furnace by means of hydraulically operated pusher gear. The drums are rolled up to the loading point, where they are placed on a hydraulically-operated platform, which loads them on to the carrier tray and turns them into a horizontal position. From this station, the trays are carried by driven rollers into the entrance chamber,



Courtesy of Modern Furnaces & Stoves, Ltd.

Fig. 14.—An oil-fired furnace for temperatures up to 1,000° C.

Courtesy of McDonald Furnaces, Ltd.

Fig. 15.—An electric furnace, rated at 105 kW., for the treatment of titanium.

which is fitted with gas-locked doors, from which the work is moved into the heating chamber and thence into the cooling chamber. At the discharge end of the cooling chamber, a further lock chamber is arranged from which the trays are withdrawn by hydraulic extractor on to a further driven-roller track, which carries the trays back to the loading end, where the drums are removed and replaced. The operation is an automatically controlled sequence, so that the operator is required only to exchange the treated drums for untreated ones at the loading station, and to operate a push button initiating the next cycle.

An oil-fired furnace is shown in Fig. 14 which is designed to cover a range of treatment up to a temperature of 1,000° C. It has a working chamber 5 ft. × 5 ft. × 2 ft. high. In this case, the furnace is heated by a single burner firing into a combustion chamber built of sillimanite brickwork below the hearth. The hot combustion products pass through side ports into the heating chamber, these ports being controlled by refractory slabs.

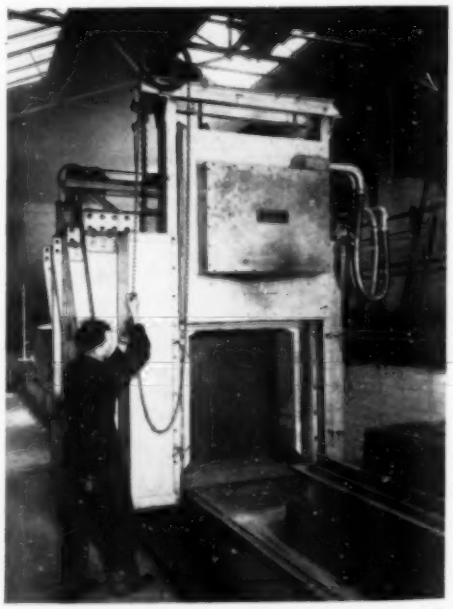
An electric furnace for the treatment of titanium sheets and pressings has been installed. This furnace, shown in Fig. 15, is designed to operate within the temperature range of 300–900° C., with close temperature uniformity over the whole range. This is accomplished by forced air circulation in conjunction with specially arranged heating elements in three transverse zones, each rated at 35 kW. and designed for pre-selected individual or combined operation, to suit the particular heat treatment requirements. The forced air circulation is effected by twin fan units positioned at the rear of the heating chamber, suitable for operating at temperatures up to 750° C., and designed to withstand the maximum operating temperature of the furnace.

Courtesy of Gibbons Bros., Ltd.

Fig. 16.—A town's gas-fired batch furnace for the treatment of special steels.

The illustration shown in Fig. 16 includes batch type furnaces, charging machine and loading tables. The furnaces are fired with town's gas, and the main heating is by means of the Gibbons-Webb roof combustion system, supplemented by the provision of long-flame burners firing into slots at hearth level. The furnaces are fitted with two-zone variable speed floating and proportional automatic temperature control and, in addition, furnace pressure control is embodied. These furnaces are 5 ft. wide × 16 ft. long.

Accuracy of control and a steady temperature rise are needed in the heat treatment of rolls, and in a gas-fired furnace installed for this purpose at the Haverton Hill plant of Davy and United Roll Foundry, Ltd., John Mathison, Ltd., use a vertical flame recirculating method of heating. The internal dimensions are 25 ft. long × 10 ft. wide bogie × 6 ft. from the bogie top to the spring of the arch, the centre of the arch being 1 ft. 6 in. higher. The refractory lined bogie hearth can take a load of 70 tons, and is mounted on turned steel wheels and axles, fitted with roller bearings. There are six groups of burners, the gas and air for which are automatically controlled from master valves at the side of the furnace.



Courtesy of The General Electric Co., Ltd.

Fig. 17.—A mobile furnace for bright annealing mild steel and carbon steel strip in lengths up to 7 ft.

A furnace installed at the works of S. A. Gilby-Fodor, at Tueil-Malmaison, France, by The Incandescent Heat Co., Ltd., was specially designed for the annealing, with mist quench, of stainless steel tubes. Fitted with compression-type sillimanite rollers in the heating zone, the furnace operates at 1,150° C., and has an output of 375 lb./hr.

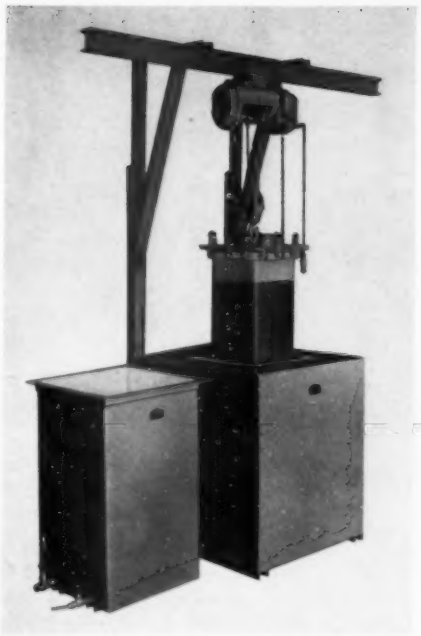
For bright annealing mild and carbon steel strip in lengths, Bruntons (Musselburgh), Ltd., have installed a mobile furnace mounted on four wheels, as shown in Fig. 17. This furnace travels along rails to any one of four working positions. The furnace is driven by a chain and sprocket, through reduction gears, from a hand winding unit, and can be moved by a single operator. At each of the working positions is a furnace base, with a refractory hearth capable of supporting a charge of steel strip in lengths up to 7 ft., stacked to a depth of 2 ft. and width of 2 ft. To allow adequate heat transfer

Courtesy of Birlec, Ltd.

Fig. 18.—Part of an installation comprising four elevator furnaces for the annealing of ferritic and pearlitic blackheart iron.

to the base of the charge, the hearth has a chequered formation. The steel strip for bright annealing is sealed within a heat resisting steel hood fitted with down-projecting flanges which seat in sand channels round the base. By using four bases, it is possible to maintain a continuous cycle of operations, comprising the loading and unloading of the bases, the purging of each new charge with protective atmosphere, and the heating and cooling stages.

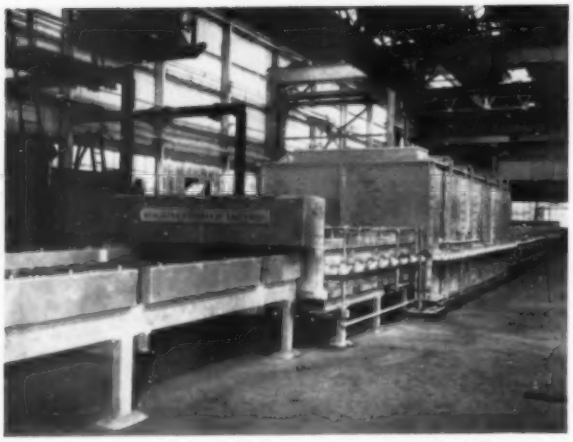
Although the elevator type of furnace for annealing malleable iron castings is now well known, an installation recently completed at Leys Malleable Castings Co., Ltd., has features of special interest. The installation comprises a total of four elevator furnaces having effective chamber dimensions 22 ft. × 6 ft. × 4 ft. 4 in. The furnaces comprise two pairs, one furnace of each pair being arranged to operate at 950° C. and the other at about 80[illegible]° C. The low temperature furnace in each pair is equipped for forced cooling, and may be set to follow any desired cooling curve by means of an automatic programme regulator. It should be noted that the cooling system, employing heat exchange elements, does not deteriorate the non-oxidising atmosphere established in the furnace chamber. Each furnace in this installation, which is shown in Fig. 18, is provided with three hearths, mounted on bogies, which are elevated into the bottom opening of the furnace by an electrically-operated hoist : bogies may be withdrawn from the high temperature furnaces and quickly transferred to the low temperature furnaces. The 2,900 kW. heating load for each furnace is divided into four separately controlled zones, and each furnace has a multi-point temperature recorder. The completely gas-tight construction of the furnace casings and the means of sealing the edges of the hearth when raised into the furnace, permit the establishment of a non-oxidising atmosphere in the chamber, which effectively prevents scaling of the castings during annealing, without the need for an external atmosphere generating equipment. Up to 20 tons of castings can be handled in one charge.



Courtesy of Hedin, Ltd.

Fig. 19.—Vertical loading furnace incorporating self-contained steam atmosphere generation.

For bright annealing non-ferrous metals, blueing tool steels, etc., Hedin, Ltd., have introduced a vertical loading furnace, incorporating a self-contained automatic steam atmosphere generator. The unit, which is illustrated in Fig. 19, comprises a vertical furnace with gantry and hoist ; a control unit ; a quench tank ; and a specially designed heat resisting container incorporating an automatic ball valve for filling and emptying, and retaining sufficient water for steam generation, a safety valve for surplus steam, and a thermocouple. The empty container is dipped in the water tank, and the ball valve allows a certain amount of water to be retained in the bottom when it is removed. The container is then loaded and lowered into the furnace. Steam is generated immediately, thus providing a protective atmosphere before the charge has reached an oxidising temperature. After soaking at temperature, the container, still full of steam, is returned to the water tank. The ball valve allows water to rush in, quenching



Courtesy of Metalectric Furnaces, Ltd.

Fig. 20.—A continuous roller hearth bright annealing furnace for the treatment of steel tubes up to 5-in. o.d.

takes place, and the steam generated escapes through the safety valve. When the container is raised from the tank, sufficient water is retained to generate steam for the next charge, and unloading can take place immediately. The range of manufacture—½ cwt. to 2 tons—will enable users with limited output to take advantage of bright annealing at a reasonable cost. The larger plants incorporate fan circulation to ensure rapid initial heating.

Fig. 20 shows an electrically heated continuous roller hearth bright annealing furnace, for the treatment of 2¾ tons/hr. of steel tubes, which has a loading width of 6 ft. and an overall length 190 ft. This furnace, which is rated at 450 kW., is provided with an exothermic gas atmosphere plant, which operates on town's gas processed to a correct analysis prior to being introduced into the furnace and cooling chambers.

For bright annealing small non-ferrous pressings, interesting equipment is shown in Fig. 21. This comprises a pair of mesh belt conveyor furnaces of modern type. In construction, the furnaces follow orthodox procedure, there being water-cooled inlet and outlet ducts to assist in the maintenance of controlled atmosphere conditions within the chamber, and, at the outlet end, to cool the work adequately before it emerges from the furnace. In the larger equipment, a suitable fan is mounted in the roof of the chamber to ensure proper distribution of the protective atmosphere through the large charge space. Although both furnaces are built on similar lines, the chamber construction differs. In the smaller furnace, on the left of the illustration, a maximum temperature of only 350° C. is required. In such circumstances, heavy duty heating elements are not necessary, and the chamber is therefore formed of several separately wound muffles in tandem. They are arranged to give two heating zones, one zone being controlled by an expansion type thermostat, and the second by an indicating automatic temperature controller. In the larger furnace, which has a maximum operating temperature of 700° C., the heating elements are of nickel-chromium alloy tube, which are supplied with current at low voltage by a suitable transformer, and arranged to give two heating zones. Suitable protective atmosphere is provided by a G.W.B. burnt town's gas plant.

Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 21.—A pair of mesh-belt conveyor furnaces of the latest type for bright annealing non-ferrous pressings.

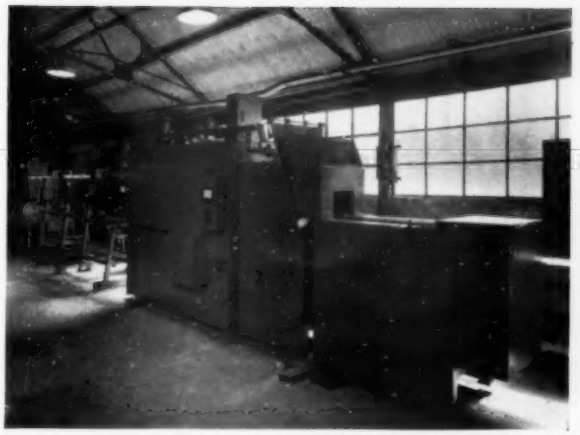
The Incandescent Heat Co., Ltd., have installed a continuous roller hearth normalising furnace in a large general engineering works in Belgium. The plant, including the furnace and cooling section is 225 ft. long, and handles 100 tons of steel sheets per day. The rollers are centrifugally cast nickel-chromium tubes.

A new design of wire mesh belt conveyor furnace for bright annealing and copper brazing is shown in Fig. 22. It has been customary to use metallic type heating elements in electric furnaces for this heat treatment, and the elements have really operated above their safe maximum temperature range. The usual metallic elements of 80–20 nickel-chromium normally operate at temperatures up to 1,050° C., but when the furnace is used for copper brazing the required temperature in the furnace is about 1,120° C. with an element temperature approaching 1,200° C. The new design of furnace illustrated has non-metallic type heating elements positioned above and below the belt. In copper brazing operations, the non-metallic elements do not reach their maximum operating temperature of 1,400° C., therefore they are not subjected to critical operating temperatures as are metallic elements. The hearth is of special articulated construction, which allows the complete assembly of the hearth to breathe freely under temperature changes. Interlocked Carborundum sections are used, and these give a very long life. The temperature of the cooling chamber is controlled automatically by aquastats, in three or more sections, to eliminate water wastage and to ensure the correct cooling temperature cycle for the product being treated. With many of these equipments, endothermic atmosphere is used ; with this type of atmosphere carbon steels can be brazed without fear of decarburisation.

A new wire patenting furnace, believed to be the largest in this country, has been designed and built by British Furnaces, Ltd., and has been installed and commissioned at the works of a well-known wire manufacturer. The furnace has an effective length of 70 ft. and an internal width of 5 ft. It is designed for an output of 2 tons/hr. when dealing with 40 ends. A new design of pre-heating zone has been incorporated in this furnace.

A Metalectric continuous bright annealing furnace recently installed for tube treatment is capable of an

output of 1,000 lb./hr. (including stainless steel tubes). The tubes are conveyed through the furnace on a woven wire belt, and roller-topped charging and discharging tables are provided. The furnace and cooling sections are purged by a special nitrogen atmosphere from an Incandescent Hi-Nitrogen generator.



Courtesy of Electric Resistance Furnace Co., Ltd.

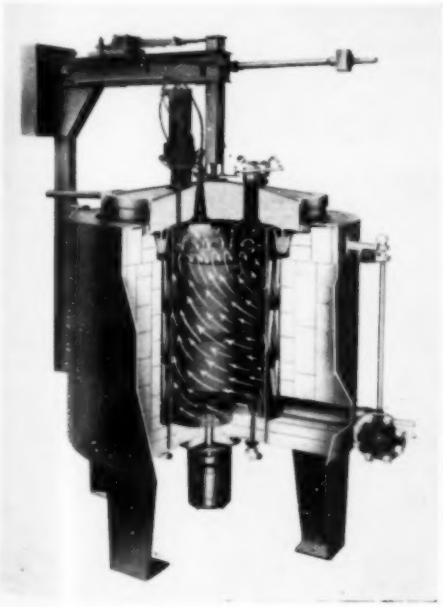
Fig. 22.—A new design of wire-mesh belt conveyor furnace for bright annealing and copper brazing.

Carburising Furnaces

Many metal components are required to resist wear, but must have ample toughness. To obtain these properties the process of casehardening, which produces a hard surface without interfering with the quality of the core, is widely used. The process usually involves the use of a carburising medium, which may be either solid, liquid or gaseous. In some cases, carbon and nitrogen are combined in the treatment to produce hard surfaces on steel components. The use of solid carburising compounds is the oldest method and is still in considerable general use, but great progress has been made in the use of both liquid and gaseous media. With the exception of salt bath furnaces, which will be considered later in this review, progress has chiefly been made in the development of gas carburising furnaces, some typical examples of which will be of interest.

In previous issues of this journal, reference has been made to the Homocarb method, in which the carburising medium is a gas atmosphere obtained by cracking a chemically constant hydrocarbon fluid directly in the furnace chamber. After normal case-hardening, the surface carbon in the case may be excessive and prove objectionable both from a quality and a manufacturing standpoint. A recent development to overcome this difficulty has now provided a means by which the carbon content of the atmosphere is automatically controlled to any specified value within the control range. Thus, for example, if a 0·9% carbon case is required to meet metallurgical specifications, the control dial is set for 0·9% carbon and all surfaces in the furnace load are maintained at this value. The carbon range covered by this control—0·15–1·15%—is wide enough to take care of all practical applications, and the temperature range of 800–950° C., over which the atmosphere control operates, is ample for diversified industrial use. The first British installation of this complete equipment, similar to that shown in Fig. 23, is at the Jaguar Works, although large numbers of them are in operation in factories in the United States; the new equipment has only recently become available in this country.

Carbon control is also valuable when hardening steel. Both structural and tool steels are susceptible to carburisation or decarburisation at hardening temperatures, if the steel and the furnace atmosphere are not in carbon equilibrium. Carbon pick-up or decarburisation may result in cracking, fatigue failure, decreased wear resistance or actual rejects. The possibility of such a difficulty can be eliminated by automatically maintaining, during the entire heat treating cycle, the carbon

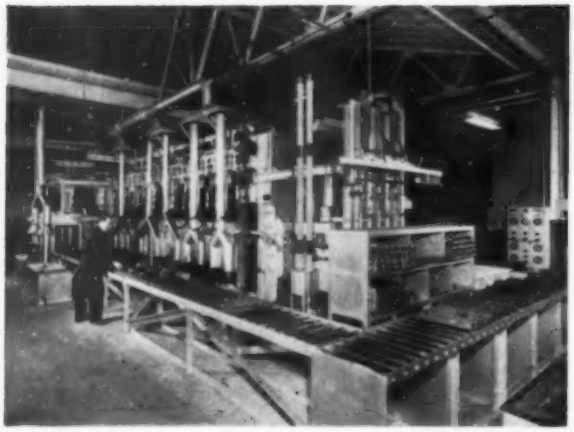


Courtesy of Integra, Leeds & Northrup, Ltd.

Fig. 23—

Left: Homocarb furnace, showing the short closed path of the furnace atmosphere, the means of introducing the carburising fluid, and the sample vent with hinged cap whereby test bars can be inserted or removed at any time during the cycle.

Right: The carbon (left) and temperature (right) recording and control panels.



Courtesy of Birlec, Ltd.

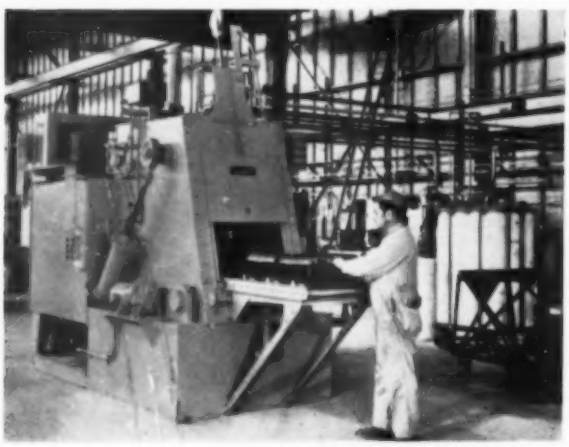
Fig. 24.—This continuous gas carburising furnace, heated by gas-fired radiant tube elements, has just been installed.

equilibrium between the furnace atmosphere and the surface content of the steel by means of this control equipment.

G.E.C. vertical batch type furnaces supplied to Vickers Armstrongs (Engineers), Ltd., for gas carburising gear wheels, are equipped with the drip feed method of producing the carburising atmosphere. The baskets carrying the charge have effective dimensions 25 in. diameter and 36 in. deep and the atmosphere is circulated through the charge by a centrifugal impeller situated beneath the stool carrying the baskets. Partial cooling is effected by admitting air through port holes in the lower part of the furnace walls and letting it circulate round the outside of the carburising chamber. Final cooling takes place in separate units having the same size and shape of chamber as the furnaces.

A new installation just completed is shown in Fig. 24. It comprises a continuous gas carburising furnace at the E.N.V. Engineering Co., Ltd. The furnace is designed for case-hardening heavy gears with an output of the order of 600 lb./hr. for a case depth of 0·055 in., requiring a total time of about 14 hours in the furnace. Gas-fired radiant tube elements are used for heating this furnace and the work, carried on trays, is moved along three parallel tracks by pusher mechanism. The work trays are carried into the entrance lock chamber on a transfer carriage, from which they are moved on to the furnace trays by pusher mechanism. A corresponding arrangement at the discharge end enables hot work to be removed from the trays manually for press quenching or, if required, to be quenched automatically in an oil tank at the end of the furnace. The transfer, door-operating and pusher mechanisms, are all interlocked to operate on an automatic time-control sequence. The heating system is arranged in four separately controlled zones, and the carburising atmosphere, which is circulated in the furnace by fans, is supplied from a battery of three Birlec endothermic generators of the gas-heated type, with arrangements for suitable hydrocarbon additions to the atmosphere to give the necessary carburising conditions.

RX gas, with or without propane addition, is fed to the appropriate zones of a three-track pusher type furnace installed by British Furnaces for the continuous gas carburising of transmission gears. The required case depth varies from 0·030 to 0·060 in., depending on the service conditions the gear has to meet. The furnace is equipped with electro-hydraulic sequence control, and the design allows for automatic side discharge and quench, or end discharge of ring gears through a manually-operated slot door.



Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 25.—Standard carbonitriding furnace utilising the Corrtherm heating element.

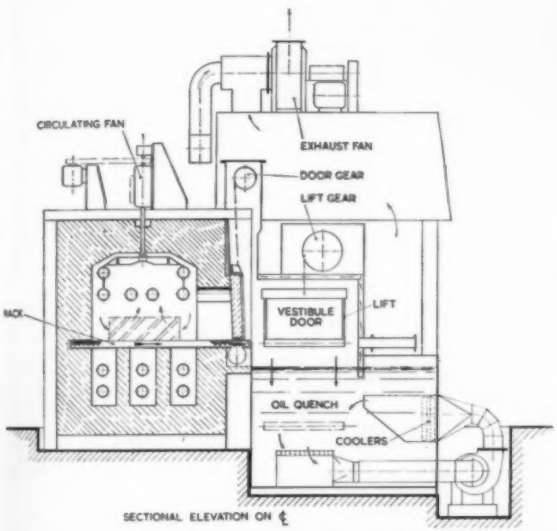
Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 26.—A Carbodrip-feed gas carburising installation comprising ten furnaces, with associated cooling pits and quench tanks.

A new design of heating element has been incorporated in the standard carbonitriding furnace shown in Fig. 25. It is a recent development of the Electric Resistance Furnace Co., Ltd., in conjunction with their associates in the U.S.A., Lindberg Engineering Company, and is known as the Corrtherm element. These elements are sheets of corrugated nickel-chromium which practically cover the entire walls of the furnace. They are hung from alloy hooks extending through the roof, making installation and replacement very simple. The corrugations give strength, and greater length for greater resistance, and they can be spaced to vary the heat

input along the length of the furnace to compensate for door heat losses or incoming cold work. The greater surface area results in lower surface temperature and, therefore, longer element life.

A gas carburising installation comprising ten furnaces, with associated cooling pits and quench tanks, is shown in Fig. 26. They provide a typical example of the use of the Carbodrip system of supplying the carburising medium. This carburising liquid is fed to each furnace through a suitable entry in a plug type door. The liquid is fed through by compressed air, and a simple flow meter is incorporated. In the furnaces, the heating elements are in the form of coils of nickel-chromium



Courtesy of Thermic Equipment & Engineering Co., Ltd.

Fig. 27.—A versatile gas-fired controlled-atmosphere batch furnace, having a working temperature range of 400–950° C.

alloy of heavy cross section, and they are graded in the chamber to ensure temperature uniformity.

A rather versatile batch type furnace recently installed is shown in Fig. 27. This furnace has a working range of 400–950° C., and provides a uniformity of heating within 2½° C. throughout that range. Thus, it can be used for clean hardening, carbonitriding, gas carburising or carbon restoration. Heating is by U-shaped radiant type tubes fired with town's gas. The burners operate on a suction system by means of a hot gas extraction fan combined with ventilation above the furnace vestibule doors. Each burner is equipped with a small recuperator to preheat the combustion air from the waste gases. The radiant tubes are arranged above and below the work, and a high velocity circulating fan is provided in the roof to ensure close temperature uniformity and rapid heat transfer. The combined water-cooled vestibule and quench tank is arranged at the front of the furnace, with a roller track approach to the quench lift. The horizontal loading system adopted ensures positive placing, minimises any handling stresses on the charge furniture, and needs little or no maintenance. All push button controls, interlocks, process timers, quench tank thermometer, temperature recording and controlling equipment, etc., are arranged in one panel

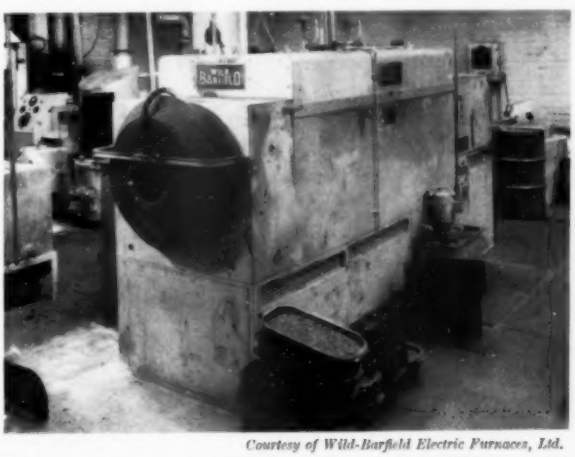
Courtesy of The Incandescent Heat Co., Ltd.

Fig. 28.—The gas carburising plant at the Dagenham Works of the Ford Motor Co., Ltd.

placed adjacent to one of the furnace vestibule doors. Ancillary equipment includes a gas-fired endothermic generator, a dewpoint recorder, and a gas-fired component washing machine.

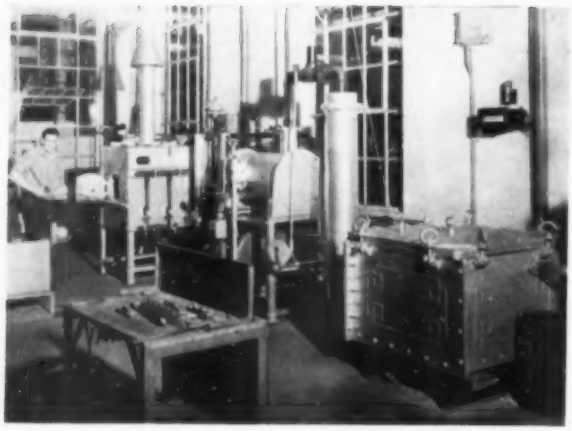
The gas carburising furnace plant installed at the Dagenham Works of the Ford Motor Co., Ltd., is shown in Fig. 28. This comprises twelve pit type furnaces, with four quench tanks, and the necessary atmosphere plant. The installation also includes complete control equipment.

One of the problems of heat treatment furnace design is that involved in the treatment of very small components. For this purpose the rotary drum furnace, shown in Fig. 29, has many advantages for carbonitriding small components, such as self tapping screws and the like. The furnace shown is heated by tubular heating elements of nickel-chromium alloy, which are so positioned that, should replacement become necessary, inconvenience is reduced to a minimum. With this in view, the furnace casing is made in halves, the upper being provided with eye bolts to enable it to be lifted clear, to facilitate inspection. The furnace drum is a



Courtesy of Wild-Barfield Electric Furnaces, Ltd.

Fig. 29.—A rotary drum furnace for carbonitriding small components.



Courtesy of Brayshawe Furnaces & Tools, Ltd.

Fig. 30.—An installation comprising muffle furnace, exothermic atmosphere generator and de-sulphurising unit for the scale-free hardening of alloy steel dies.

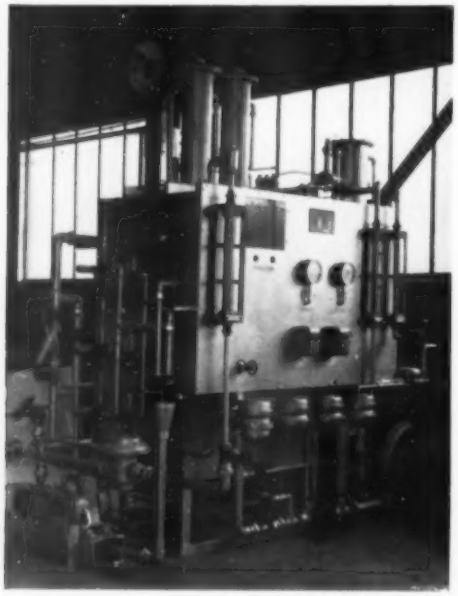
casting of heat-resisting material having an internal helix, work thus being progressed from end to end as the drum revolves. Gas seals are incorporated to maintain a consistent atmosphere within the drum itself, which thus functions as a retort. Outputs naturally vary according to the nature of the work and the case depth required, but for such components as self tapping screws, with a case depth of, say, 0·005 in., a figure of the order of 115 lb./hr. is quite usual and, taking the treatment time into account, represents an economical production flow with a power consumption of about 15 kWh. for this application.

The installation shown in Fig. 30 is a typical controlled atmosphere small batch furnace for the scale-free treatment of carbon and alloy steel dies at temperatures within the range 650–1,050° C. The complete plant comprises a full muffle furnace, with working dimensions 12×12×18 in., an exothermic atmosphere generator, and a desulphurizing unit. The furnace is heated by town's gas, the burners being arranged to fire alternately from each side below the muffle, with the products of combustion passing completely round the muffle before exhausting to the atmosphere, via a damper-controlled flue stack. Each burner is fitted with gas and air taps with individual adjustment, main control of the furnace temperature being effected by overriding valves in the main gas and air supply lines.

Furnace Atmosphere Plants

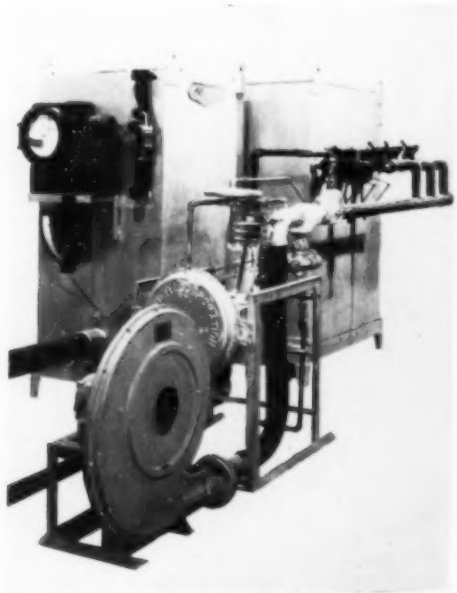
Reference to many types of gas generating plant has been made in these columns over many years, but several plants have been developed more recently. Among these is that shown in Fig. 31. These units are made in standard sizes in the range 800–5,600 cu. ft./hr., and produce uniform atmospheres for dry cyaniding, gas carburising, homogeneous carburising or carbon restoration. As generated, RX gas is suitable for bright annealing and clean hardening low and medium carbon steels, and, if enriched with propane, may be used for bright annealing and clean hardening of high carbon steels. In one application of this generator, transmission gears are being treated in a British Furnaces continuous gas carburising furnace to obtain case depths that vary with the type of gear and its duty, the bulk of gears treated calling for 0·03–0·04 in. or 0·04–0·05 in., with some heavier gears going up to 0·06 in. Normally, a carbon content of 0·9–1·0% is required in gear cases.

A novel type of atmosphere plant is shown in Fig. 32. It was specially designed in connection with a McDonald electric roller hearth furnace having a 3-ton/hr. output, for installation in South Africa, where no conventional



Courtesy of British Furnaces, Ltd.

Fig. 31.—A standard RX gas generating unit for gas carburising.



Courtesy of McDonald Furnaces, Ltd.

Fig. 32.—A kerosene gas atmosphere plant.

gas was available to provide the necessary protective atmosphere. The plant comprises three main parts : an electrically operated kerosene mixing unit for generating a combustible air-gas mixture of predetermined ratio ; a combustion chamber fitted with controlled firing for producing incomplete combustion of the air-gas mixture to obtain the required CO_2 content of the atmosphere gas ; and a gas cleaning and cooling unit. The ancillary equipment includes a gas flow indicator and CO_2 recorder.

The use of various atmospheres in laboratory and small production units is now common practice for such processes as bright hardening, bright annealing, brazing, and annealing of special steels for maximum electrical properties. Besides generated atmospheres, cylinder gas, such as hydrogen and argon, is sometimes used. The difficulty experienced with the former has been associated with suitable generating equipments, the smallest producing gas far in excess of requirements. To overcome this difficulty, the small generator shown in Fig. 33 has been designed and produced. This generator is rated at 35 cu. ft./hr., and produces a 75% hydrogen, 25% nitrogen atmosphere by completely dissociating raw liquid ammonia over a heated catalyst.

Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 33.—A small atmosphere generator for small production units.

Furnaces for Hardening and Tempering and for Solution and Precipitation Treatments

The size and design of components, as well as the materials of which they are made, frequently present problems associated with their treatment. This is particularly true of continuous furnaces dealing with irregular components, which are required to maintain a continuous flow of accurately treated work. An interesting example of this is the recently installed plant for the continuous hardening and tempering of steel forgings shown in Figs. 34 and 35. Many steel forgings, because of their shape, are preferably heated and quenched in the vertical position, to avoid or reduce distortion, and the method has been incorporated in this design.

This rather exceptional plant has been designed and built for the treatment of 3,150 lb./hr. of steel forgings, which are carried through the furnace in a vertical position by means of a mono-rail conveyor system. The overall length of the installation is approximately 70 ft., with a width of 25 ft. and a maximum height to the top of the vertical cylinders of 21 ft. The two furnaces forming the main part of the installation are each about 33 ft. long, and are fired from the side walls by automatic proportioning gas burners, arranged in a staggered formation. The hardening furnace has a maximum capacity of 7,200 cu. ft./hr., and the tempering furnace 4,400 cu. ft./hr.

An interesting feature of the design of these furnaces is the mono-rail conveyor system, which consists of a longitudinal joist suspended from cross members of the casing and arranged above the slots in the roof. Four-wheeled trolley carriers ride on this mono-rail and carry

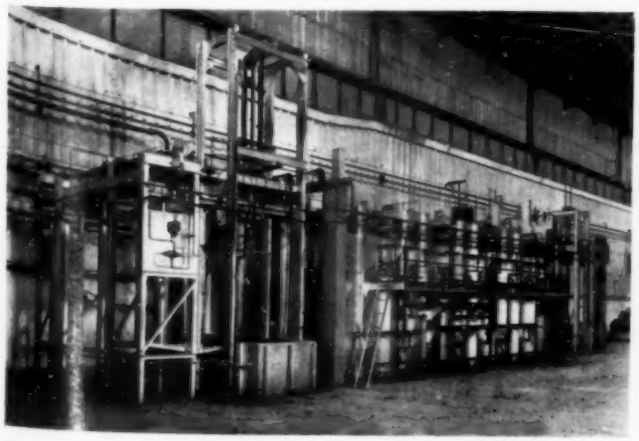
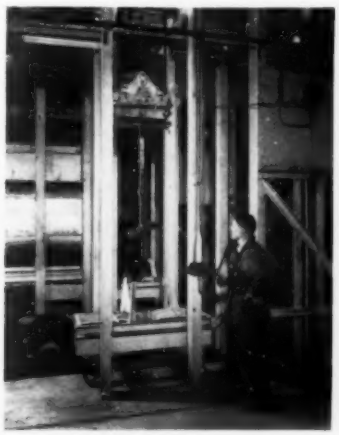
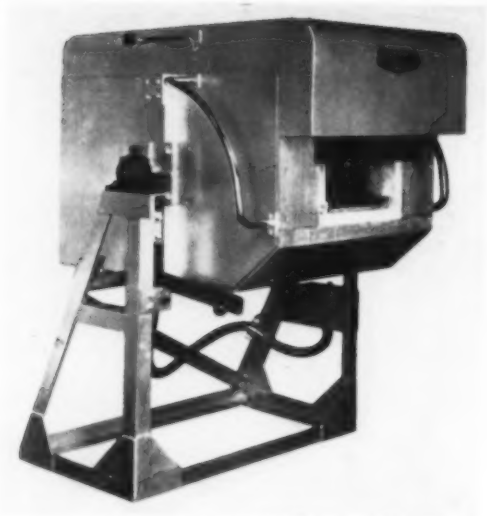


Fig. 34.—Part of an automatic hardening and tempering installation for forgings, showing the outlet end of the hardening furnace with the door open, the quench tank, and the cross conveyor mechanism.



Courtesy of Dowson & Mason, Ltd.

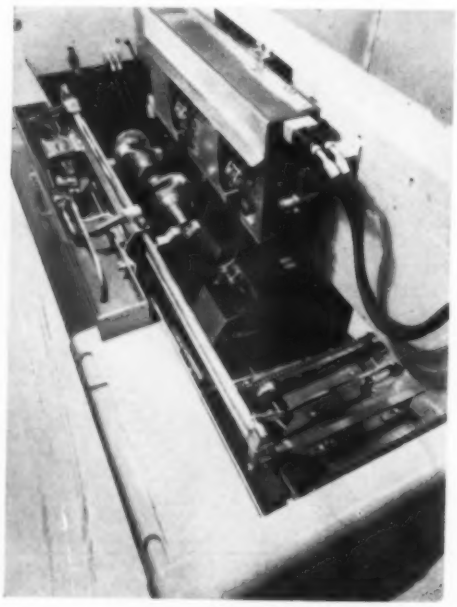
Fig. 35.—Showing means of raising forgings from transfer bogies into position for suspension from the mono-rail track.



Courtesy of McDonald Furnaces, Ltd.

Fig. 36.—An electrically-heated tilting type hardening furnace.

vertical heat-resisting alloy steel bars suspended through the slots, and from these bars the forgings are hung. Seal plates designed to float on the vertical carrier bars minimise the heat loss which would otherwise occur, but on either side of the top of the roof slots, horizontal water-cooled skid rail tubes are provided. The general sequence of operations is that the forgings are brought to the charge end of the hardening furnace and are lifted by means of a hydraulic cylinder so that they are suspended from one of the four-wheeled trolleys. At predetermined intervals, controlled by an electric clock, hydraulic cylinders open the discharge doors of both furnaces, which allows other horizontally mounted cylinders to extract a set of forgings and bring them into position over a quench tank and into an air cooling chamber situated at the ends of the hardening and tempering furnaces respectively. When these operations have been performed, the discharge doors are automatically closed, and simultaneously the forgings over the quench tank are lowered by another hydraulic cylinder into a 2,300 gallon capacity water quench tank, from which they are moved again automatically after a predetermined time interval. The removal of one set of forgings from the discharge end of each furnace leaves spaces which are filled by moving the row of forgings in each furnace through the distance of one trolley, this being accomplished by first automatically lowering the two discharge doors, which brings into operation the retractable head pushers mounted on top of the monorails, which move a fresh set of forgings into each furnace, and at the same time move all forgings already in the furnaces nearer to the discharge doors. This plant allows for completely automatic operation of the charging and discharging, and of the quenching and the transference from one furnace conveyor line to the other, and provides a good example of automation in furnace design.



Courtesy of Electric Furnace Co., Ltd.

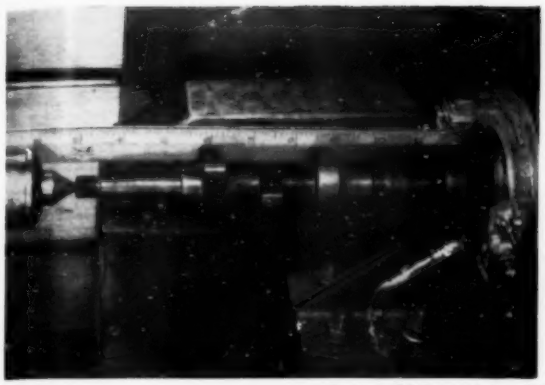
Fig. 37.—A semi-automatic crankshaft hardening unit designed for an output of 30 shafts per hour.

Recently installed at the Sheffield Works of Thos. Firth and John Brown, Ltd., is a battery of four Brayshaw bogie hearth furnaces specially designed for precision heating at temperatures from 150–800° C. Accurate control to $\pm 2\frac{1}{2}$° C. is achieved by the use of an external combustion chamber and the recirculation of large volumes of hot gases through the work chamber in a closed system of ducting. The recirculating gases are arranged to flow across the width of the furnace, and the flow direction is changed every three minutes by an automatic reversing mechanism. The doors are electrically operated, and the bogie is moved by rack and pinion.

Another new design, but of small dimensions, is the electrically heated 12 kW. tilting-type hardening furnace shown in Fig. 36. This furnace is designed for temperatures up to 1,000° C., primarily for hardening small spring washers, for which it has an average output of 100 lb./hr., working at a temperature of 850° C. Work treated can be discharged by a hand operated mechanism direct into a quench tank containing wire baskets for drainage purposes.

Probably the first example of high-frequency induction heating for hardening was its application to crankshafts and many such units have since been installed. The unit shown in Fig. 37, recently supplied to F. Perkins, Ltd., of Peterborough, is a semi-automatic crankshaft hardening unit, and uses the type of inductor described in last year's review. In this equipment, the crankshaft is loaded on to a trolley at the far end and the operator presses a button. The crankshaft is moved by a conveyor mechanism to the first of the two heating positions, in which the main end journals are heated and quenched: then to a second position, where the intermediate mains are hardened. The hardened crankshaft is then moved to an unloading bay, where it is deposited by the conveyor, the trolley returning to the loading position. A second trolley has meanwhile been loaded and the cycle re-commenced.

For small shafts at reduced output, a simple form of progressive hardening fixture may be used. This is the



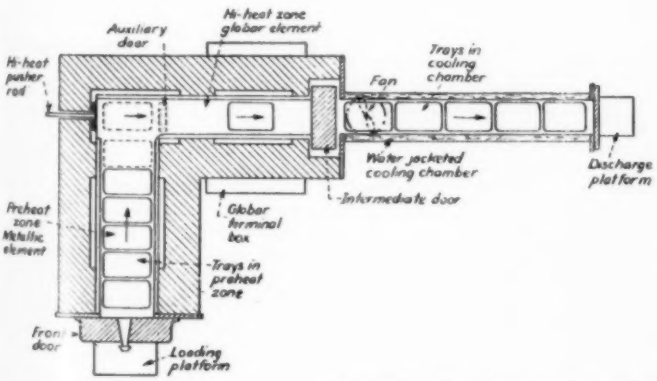
Courtesy of Delapena & Son, Ltd.

Fig. 38.—Equipment for hardening working and bearing surfaces of camshafts, using high-frequency heating.

Toccotrol, supplied by the Ohio Crankshaft Company, U.S.A., a British-made version of which is now being manufactured by Electric Furnace Co., Ltd., for use with motor alternator sets of appropriate rating. This equipment can be used for all progressive or intermittent hardening of shafts.

The surface hardening of the ways of lathe beds by induction heating has been successfully developed by Electric Furnace Co., Ltd. Because of the increased loadings necessitated by higher outputs, many lathes are now provided with hardened ways. These can be provided by the insertion of hard metal strips, or they can be progressively hardened inductively. The inductor is mounted on a saddle and moved along the way at a predetermined speed. A 50 kW., 10 kc./s., motor alternator provides the high-frequency current.

For the heat treatment of carburised Cu 32B camshafts used in the construction of Diesel fuel injection pumps, a 75 kW. vertical motor generator equipment has been used in conjunction with an automatic handling fixture, which enables a single turn inductor with an inside diameter of $2\frac{3}{16}$ in. to be traversed along the axis of the component. Attached to the coil is a circular spray quench ring (see Fig. 38). The camshaft is mounted between centres and rotated at a controlled



Courtesy of Electric Resistance Furnace Co., Ltd.

Fig. 40.—Cross-sectional top view of the EFCO-Lindberg "L-type" furnace showing constructional features and flow of work through furnace.

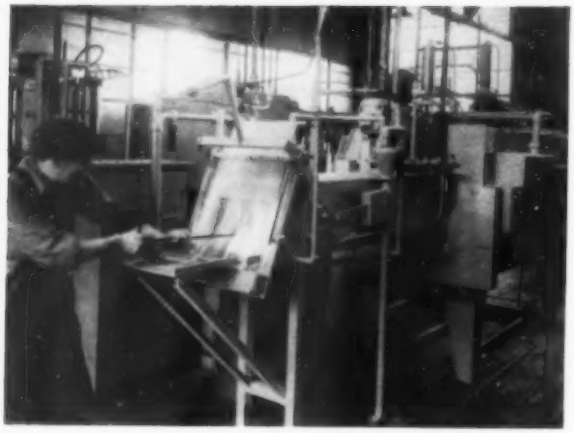
Courtesy of The General Electric Co., Ltd.

Fig. 39.—A gear being removed from a roller hearth furnace for quenching.

speed, whilst the coil/quench ring assembly is moved progressively along the length of the component. With the power switched on and off at predetermined intervals, the areas to be hardened are heated and quenched to give a hardness of Rockwell C62. Using a single coil, the time of traverse for hardening the cams is 7·4 sec./in., and for the smaller diameter journals, 15·6 sec./in. The threaded end of the shaft is subsequently induction annealed as a separate operation.

Among the heat treatment furnace installations recently commissioned in one of the works of Vickers-Armstrongs (Engineers), Ltd., is an electrically heated roller hearth furnace for hardening gear wheels, shown in Fig. 39. The gears are heated in an atmosphere generated in the furnace from liquid introduced by the drip feed technique. The furnace has a heated length of 15 ft. and a maximum rating of 100 kW. The elements, which are of the heavy gauge nickel-chromium ribbon type, are mounted in the roof and in the hearth, and are arranged in independently controlled zones: the furnace operates at temperatures up to 1,000° C. The gears are inserted into the furnace on trays, and moved continuously along by the rollers, driven by an induction motor through reduction gears. The time taken for the gears to pass through the furnace can be varied from 31 to 155 minutes, the actual time being shown on a tachometer mounted near the drive unit. As the charge approaches the discharge end, it breaks a beam of light falling on to a photo-electric cell and an alarm bell rings to warn the operator that a charge is ready to be removed. The doors at both ends are suitably counterbalanced and are operated hydraulically by foot controls. Cradles and idle rollers are provided to facilitate loading and unloading.

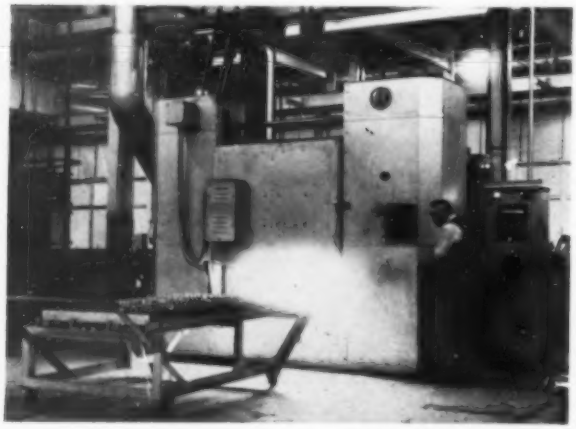
Because of the high temperatures involved, the hardening of high speed tool steels totally free from scale, decarburisation or carburisation, has always been a difficult problem. The Efco-Lindberg L-type furnace was primarily developed to harden precision high speed steel tools with cutting edges which could not be ground



Courtesy of Electric Resistance Furnace Co., Ltd.

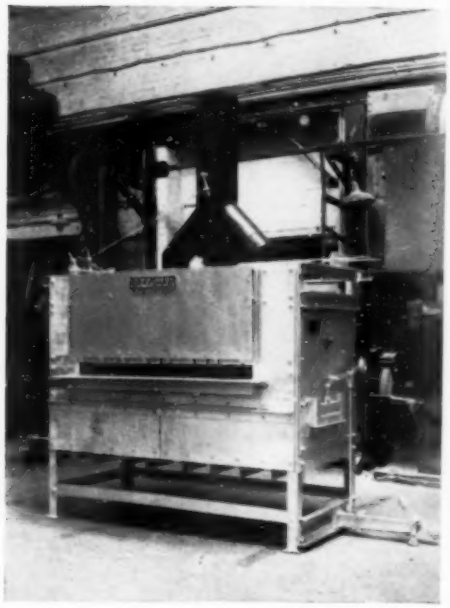
Fig. 41.—Tray of work being withdrawn from end of cooling chamber of L-type furnace. The endothermic atmosphere generator is shown in the background on the left.

or cleaned after hardening. The furnace is unusual in construction, in comparison with conventional furnaces designed for similar work. It consists of preheat, high heat and quench all built into one complete unit, as shown in the line drawing Fig. 40. The work enters the furnace cold, and does not again contact the air until it has been quenched. An unusual feature of the design is that the preheat is built at right angles to the high heat. The quench unit follows directly behind the high heat unit, and is designed to quench the steel by means of a forced convection, cooled, protective atmosphere. Sections of high speed steel up to 2½ in. can be fully hardened by the atmosphere quench. The heating elements in the preheat zone are of the metallic type, and in the high heat zones of the non-metallic type, which will not warp or melt, but provide excellent heat transfer. The temperature in both zones is separately and automatically controlled. Tools to be hardened progress through the furnace in trays. The preheat section holds five trays, the high heat one tray, and the quench five



Courtesy of G.W.B. Furnaces, Ltd.

Fig. 43.—One of a series of batch furnaces for heating Nimonic parts in the works of a manufacturer of jet engines.



Courtesy of Brayshaw Furnaces & Tools, Ltd.

Fig. 42.—A gas-fired high temperature slot furnace for treating high speed steel.

trays. The work is cooled to below 200° C. so that it will not discolour when removed from the quench and cooling chamber. A tray of work being withdrawn from the end of the cooling chamber is shown in Fig. 41.

A more conventional type of furnace for the treatment of high speed tool steels is shown in Fig. 42. This is a gas-fired high temperature slot furnace, with a working slot 4 ft. 9 in. by 3 in. high and 9 in. deep, and a preheat chamber 1 ft. wide by 3 in. high fitted at the side. The high temperature chamber is designed for temperatures of 1,100/1,350° C. The burner equipment, which is fitted with heat resisting nozzles, is located at the back of the furnace, and fires direct into the main heating chamber above the level of the working opening. The products of combustion are arranged to circulate round this chamber before passing to the preheat chamber below, and are finally used to preheat the air supply to the burners. The front panel of the furnace is removable to allow easy access to the furnace chamber for inspection and replacement. To protect the furnace operator from the direct heat, an air screen is provided across the full width of the working slot.

A batch type furnace with mechanised quenching equipment for the solution treatment of aluminium sections has been installed by The Incandescent Heat Co., Ltd., for use in the aircraft industry, where accurate metallurgical results are required. The charging and discharging mechanism is so designed that a charge can be withdrawn from the furnace and fully quenched within 15 seconds. Larger units up to 40 ft. long have been designed and built for the treatment of complete aircraft spars. In this case, a 40 ft. long spar can be extracted and fully quenched within 20 seconds.

G.W.B. supply a number of batch furnaces for the heat treatment of Nimonic alloys and other heat resisting materials used in the manufacture of jet engines. The furnace shown in Fig. 43 is a high tem-

perature resistance heated unit operating at a maximum temperature of 1,050° C. with a rating of 60 kW. The internal dimensions are 4 ft. 6 in. long × 6 ft. 3 in. wide × 2 ft. 6 in. high, and special cast heat resisting steel trays are fitted in the hearth to support the charge pieces.

Salt Bath Furnaces

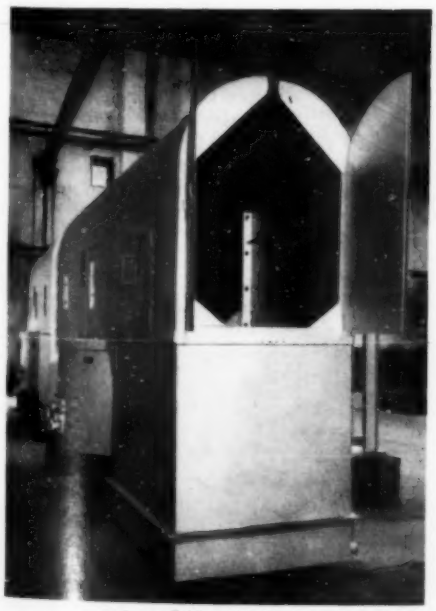
The sequence of operations involved in many heat treatments can be satisfactorily carried out in salt bath furnaces. This method of heating has certain advantages and continues to make progress. The basic advantages of salt baths are simplicity of operation; the ease at which results are reproducible; the excellent finish on work treated; and the minimum of technical skill necessary for their operation. For some years attention has been directed to the design of partially and totally enclosed plants, and to automatic operation, and further progress has been made in installations of I.C.I. fully automatic type D.G. furnaces, with total enclosure, for case-hardening parts in cyanide-containing salts. These enable fume to be suitably collected and dispersed. Alternatively, cheaper totally enclosed batch type salt bath furnaces, similar to Fig. 44, have been installed for case-hardening cycle parts. In these latter, work is handled from an overhead runway, the suspending chain passing through a slot in the enclosed canopy which covers preheater, salt bath and quenching tank.

During the past year, several fully automatic totally-enclosed salt bath furnaces, similar to that shown in Fig. 45, have been built or installed for martempering or austempering, including martempering of En. 31 steel bearing rings, and En. 34 steel gears. This method is considered to result in a reduction of distortion, compared with oil quenching. A greater number of martempering and austempering plants are, however, of the hand-operated batch type, transfer from the salt bath used for austenitising to the salt bath for martempering or austempering being effected manually. The application of salt bath furnaces, employing neutral salts for hardening high speed steels without decarburisation, continues to make progress. Fig. 46 illustrates an installation for hardening large taps and dies, including salt baths for preheating, high temperature heating, quenching and secondary hardening.

Courtesy of Imperial Chemical Industries, Ltd.

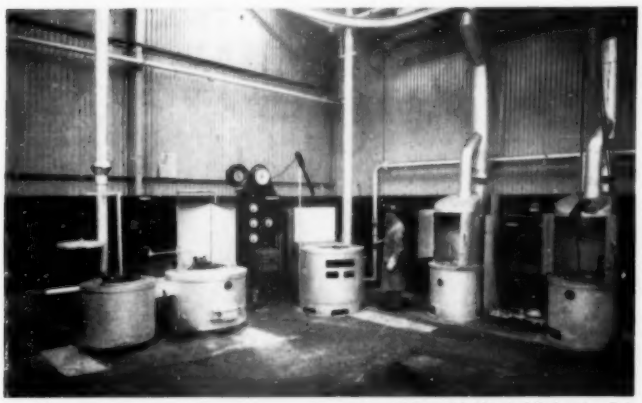
Fig. 45.—A totally enclosed, fully automatic salt bath furnace.

A complete installation for the treatment of carbon and alloy tool steels in the new heat treatment division of Uddeholm, Ltd. (Fig. 47) comprises eight furnaces (including salt baths), four quench tanks providing oil and water quenching, and a low temperature oven. Three electrode salt bath furnaces provide a range of operating temperature for the hardening of tools and dies, and ensure rapid and uniform heating, whilst providing protection from scaling and decarburisation. A 37·5 kW. salt bath operates at temperatures up to 1,350° C., meeting the requirements for hardening high speed steels and certain hot die steels. Its capacity is 8 in. diameter × 14 in. deep. Two baths, each of 36 kW rating, are used for the bright hardening of tool steels:



Courtesy of Imperial Chemical Industries, Ltd.

Fig. 44.—A totally enclosed, batch type, salt bath furnace for case-hardening cycle parts.



Courtesy of Imperial Chemical Industries, Ltd.

Fig. 46.—An installation for hardening large taps and dies, including salt baths for preheating, high temperature heating, quenching and secondary hardening.

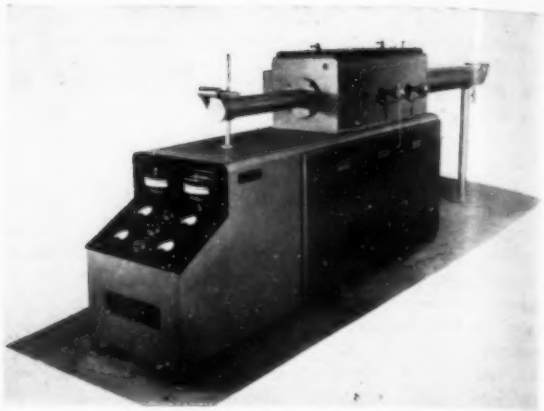
Courtesy of The General Electric Co., Ltd.

Fig. 47.—The heat treatment shop at the Crown Works of Uddeholm, Ltd. for the treatment of a full range of carbon steels.

one, with a ceramic pot 12 in. diameter × 16 in. deep, operates at temperatures up to 1,000° C.; the other, with a calorised mild steel pot of the same dimensions, provides for temperatures up to 950° C., and can be used for cyaniding. In addition, there are two rectangular salt baths heated by immersion heaters; one providing temperatures up to 350° C. and used for martempering tool steels to reduce risks of cracking and distortion; and the other suitable for treatments at temperatures up to 600° C., including the secondary hardening of high speed and hot die steels. In both these baths, the molten salt is kept in circulation by an easily removable electrically driven stirring paddle. A 30 kW. horizontal batch furnace is included in this installation for hardening and pack carburising of tools which are too large for salt bath treatment and for annealing. For water quenching, two tanks, of 200 and 400 gallons capacity, respectively, and containing a 5% caustic soda solution, are used. The solution in each is kept in circulation by being continually pumped from the top and returned to the bottom. Oil quench tanks of 450 and 300 gallons capacity have immersion heaters to raise the temperature of the oil to the normal quenching temperature of

Courtesy of Sintering & Brazing Furnaces, Ltd.

Fig. 48.—A humped back conveyor furnace for sintering or copper brazing with controlled atmosphere.



Courtesy of Sintering & Brazing Furnaces, Ltd.

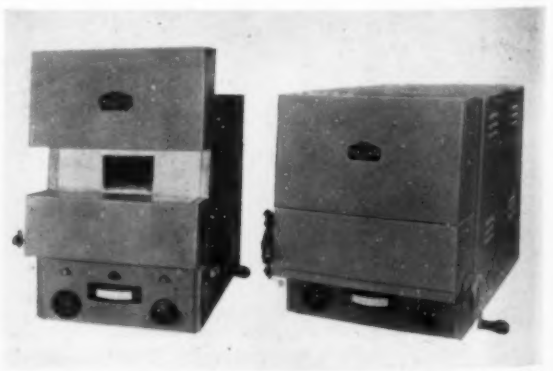
Fig. 49.—A 4-in. molybdenum-wound tube furnace for temperatures up to 1,750° C.

40–50° C. All the quench tanks have immersed water carrying coils for cooling the quenching medium.

Special Furnaces

So many factors are involved in heat treatment operations that variations in design of equipment to carry them out may be necessary, particularly for new alloys or in the modification of techniques applied in existing processes. New designs of furnaces may be developed on a laboratory scale to facilitate research. In last year's review reference was made to the development of a furnace by the General Electric Co., Ltd. for the sintering of carbides and other refractories, and the specialised heat treatment of titanium, zirconium, and tantalum, requiring temperatures above 1,800° C.

In Figs. 48 and 49 are two smaller furnaces which may be included in this category. The former, having a humped back design, is being used for the sintering of metal powders, copper brazing and bright annealing. Although this particular example is designed for temperatures up to 1,150° C., humped back pusher type furnaces are being built for temperatures up to 1,450° C. These furnaces have fully automatic control. Fig. 49 is one of a number of laboratory type furnaces which have been developed, either for laboratory use or for small scale production work. It is a tube furnace with a temperature range up to 1,750° C. Other types of



Courtesy of Hedin, Ltd.

Fig. 50.—Left, 1,000° C., and right, 1,400° C. bench type electric furnaces.

tubular furnaces have been made in which nickel-chromium, Kanthal or molybdenum wound tubes are incorporated for temperatures up to 1,800° C.

Two new bench type furnaces marketed by Hedin, Ltd. (see Fig. 50) have maximum operating temperatures of 1,000° C. and 1,400° C., respectively. The former has heavy gauge 80–20 nickel-chromium alloy heating elements, and is provided with a heavy gauge Inconel muffle to protect the refractory. Like the 1,000° C. model, the high temperature furnace has easily changed heating elements—in this case, the latest type of silicon carbide elements: overheating of the terminals is prevented by water cooling. To withstand thermal shock, a very robust Carborundum hearth is fitted. Both furnaces have counterbalanced doors, rising and falling on an incline so as to provide an extremely good seal. Heat resisting containers for use with protective atmospheres are also available.

Conclusion

Although it has not been possible to refer to all the interesting installations put into commission since the last survey, partly through lack of space, but also because details have not come to hand in time to be included, the examples given are typical of the developments achieved during the year. To those who are familiar with heat treatment shops and plant of earlier years, the cleanliness of operations, to which furnace designers have given invaluable assistance, is an outstanding feature in modern practice. In addition, the developments introduced have advanced the art of heat treatment, enabling successful treatments to be reproduced with a very high degree of accuracy.

Acknowledgments

We are greatly indebted to those firms who have supplied information and photographs, and take this opportunity of expressing our sincere appreciation to them, and to the firms in whose works the various plants are installed, for permission to publish the details and illustrations.

N.P.L. Open Day

Progress in the Metallurgy Division

FOR many years now, the Metallurgy Division of the National Physical Laboratory has made important contributions to the study of the metallurgical aspects of creep, such as the relation of microstructure to creep resistance, and the complex changes taking place in precipitation-hardening materials under creep conditions. This work continues to form an important part of the Division's activities, as does the fundamental work on the constitution of alloys and the basic structure of metals. Developments in other fields, however, have called for fundamental investigations of new materials, a striking example being the titanium alloys, which are now no longer merely of laboratory interest. The atomic energy field, in its turn, needs information on the constitution and properties of alloys of such metals as uranium. On the other hand, metallurgical research workers have benefited from the labours of those working on atomic energy problems, in that radioactive tracer techniques provide useful means of investigating many metallurgical problems. On the occasion of the recent Open Day at the Laboratory, the exhibits and demonstrations in the Metallurgy Division illustrated these and other activities in the metallurgical field, and in the following notes reference is made to the work behind a few of the more interesting items on show.

Preparation of High-Purity Iron

In the study of the properties of binary and ternary alloys of iron, it is essential to use very pure materials. Certain elements, such as phosphorus, carbon and nitrogen have a very marked effect on the properties of these alloys, even when present in amounts as low as 0·001%, and it has become necessary to reduce the contents of these elements well below this level.

Sulphur has until now resisted efforts to reduce its concentration to an acceptable level, particularly on the scale of production required, namely ½ cwt. per week. An electrolytic method of purification has now been developed whereby the concentration of sulphur can be reduced to a few parts per million.

The novel feature of the method is the division of the electrolytic cell into two compartments by means of a cation-permeable membrane, which has the property of preventing the passage of anions from the anolyte to the catholyte, whilst freely allowing the passage of ferrous ions. The sulphur contained in the impure anode is thus prevented from reaching the neighbourhood of the cathode. It is found that to attain the desired purity in the cathode deposit the catholyte must be free from any trace of sulphur, and when this condition is satisfied the sulphur content of the deposit is below the limit of detection by analysis, that is, below 3 parts per million.

Uranium-Palladium Alloys

In connection with a programme sponsored by the Atomic Energy Research Establishment, the equilibrium diagram of the system uranium-palladium has been investigated by metallographic and X-ray methods. The system is complex, and in addition to the terminal solid solutions, the phases existing have compositions corresponding to the compounds UPd, U_5Pd_6 and UPd_3. The solubility of palladium in γ-uranium is limited, and is negligible in the β and α modifications. The most interesting feature of the work has been the discovery of a considerable solid solubility of uranium in palladium. The electronic structure of palladium in the solid state is well-established, and consequently measurement of certain of the physical properties of the palladium-rich palladium-uranium alloys enabled an estimate to be made of the effective electron contribution of uranium to the band structure of the alloys. The physical properties included the lattice parameter, paramagnetic susceptibility, thermoelectric power and electrical resistivity. These measurements suggest that uranium dissolves in dilute solution with an effective valency of six, but as the concentration increases most probably behaves with a valency of four.

Diffusion of Antimony in Copper

The development of nuclear reactors for power has, in

recent years, produced a readily available supply of those most useful by-products, the radioactive isotopes of the elements. These isotopes are finding increasing application in metallurgy, especially in the study of the movements of metal atoms amongst their own kind (self-diffusion), and amongst the atoms of other metals (chemical diffusion).

Tracer techniques are being used in the Metallurgy Division to study diffusion processes in the system copper-antimony. The rate of diffusion of antimony into copper through the normal metal lattice, and along the grain boundaries, is being measured at very low antimony concentrations, using a radioactive antimony isotope. Copper single crystals are used to determine the normal lattice diffusion rate. In this way, the complications due to the presence of grain boundaries are avoided, and a more reliable result is obtained. Diffusion of antimony into copper single crystals has been measured over a wide range of temperature, and the results obtained agree well with the data available in the literature for similar systems, and with current theories of diffusion in very dilute solution. Polycrystalline material will be used to measure the grain boundary diffusion rates, and the results will be compared with those from the single crystal work. The effect of increasing antimony concentration on the normal lattice and grain boundary diffusion rates will also be measured. It is hoped that these studies will throw light on the well-known phenomena of intergranular brittleness, which has recently been observed in copper-antimony alloys by other workers in the Division. In particular, the antimony diffusion rates along the grain boundaries of copper and copper-antimony alloys should provide fairly direct evidence for or against the current idea that intergranular brittleness as caused by the segregation of the " foreign " atoms to the grain boundaries.

Personal News

MR. T. POWELL has been appointed Managing Director of British Acheson Electrodes, Ltd., in succession to MR. W. B. H. GALLWEY who was recently appointed Chairman of the Company. Mr. Powell, who is 47 years of age and a native of Sheffield, is Divisional Managing Director of British Electro Metallurgical Co. (A Division of Union Carbide, Ltd.), and also a Director of Union Carbide, Ltd.

MR. P. B. H. CUFF has been appointed a Director of Solartron Electronic Business Machines, Ltd.

DR. F. ZERNIKE has been elected a Foreign Member of the Royal Society. He is well-known for his researches in phase-contrast microscopy.

MR. J. G. THOM has been appointed Northern Ireland Sales Manager for British Oxygen Gases, Ltd.

MR. F. G. KAY, Sales Manager of Acheson Colloids, Ltd., is at present on a three months' tour of South America, with the object of establishing sales organisations for " dag " dispersions of colloidal graphite and molybdenum disulphide in the principal industrial centres there.

THE resignation of MR. P. WRIGHT, Rolling Mills Superintendent at Steel, Peech and Tozer Branch of The United Steel Companies, Ltd., who is leaving on 30th June, 1956, to take up an appointment outside the company, has necessitated a number of changes. With effect from 1st May, MR. F. P. WRIGHT has been appointed Strip Mill Manager, and MR. J. K. WALSHAW, Assistant Strip Mill Manager. From 1st July, MR. W. E. ALEXANDER, at present Strip Mill Manager, will become Rolling Mills Superintendent; MR. N. D. THOMSON will be Brinsworth Mill Manager; MR. F. TEW, Assistant Brinsworth Mill Manager; and MR. W. F. STROUGHHAIR, Assistant Bar Mill Manager. The final appointments will take effect from 1st August, when MR. N. STONES becomes Assistant Manager of the 10 in. and 14 in. Mills; and MR. G. MORRIS, Shift Superintendent, Bar Mill.

HADFIELDS, LTD., announce the appointment of MR. F. HOLMES as Chief Purchasing Officer, in succession to MR. J. E. GUEST who has been released to take up special duties prior to retirement.

MR. H. DE G. WARTER has been appointed Public Relations Officer to the Regent Oil Co., Ltd., and MRS. V. G. ELELMAN has been appointed Assistant to the Public Relations Officer and Editor of *The Regent Journal*.

MR. G. B. HAYWARD, formerly Manager of the Plymouth Sub-Office, has been appointed Manager of the Bristol Sub-Office of Metropolitan-Vickers Electrical Co., Ltd., in succession to MR. H. B. ECCLES who has reached retiring age and is at present acting in an advisory capacity. MR. J. S. HALL, formerly Assistant Manager of the Company's Manchester Office, has been appointed Assistant Manager at Cardiff.

MR. J. R. RYLANDS, Chief Engineer and a Director of E. Green and Son, Ltd., fuel-economiser makers, Wakefield, succeeds in October next MR. R. H. GUMMER as President of the Institute of Fuel.

MR. R. A. PITMAN has been appointed secretary of the British Engineers' Association in succession to BRIGADIER J. V. TOPHAM, who has resigned to take up another appointment.

MR. E. C. HOLROYDE has joined the Board of Lightalloys, Ltd.

Obituary

WE regret to record the death, on 29th April, of Mr. O. W. MORTIMER, representative of The Effingham Steel Works, Ltd., Washford Road, Sheffield, for the West Riding of Yorkshire, Lancashire and the North Midland Area. Mr. Mortimer, who was 66, was a Local Director of the Company.

M.V. Offices at Swansea and Edinburgh

METROPOLITAN-VICKERS ELECTRICAL CO., LTD., announce the change of address of the Company's sub-offices at Swansea and Edinburgh. The new address of the Swansea sub-office is 166, St. Helen's Road, Swansea, and of the sub-office at Edinburgh, 61A, Queen Street, Edinburgh, 2. Both changes came into effect during May.

Change of Address

As from 28th May, 1956, the address of The Anglo Metal Co., Ltd., is Garrard House, 31–45, Gresham Street, London, E.C.2. Telephone No.: MONarch 8800 (PBX); Telex: 2–2479; Telegrams: Nucliform, London, Telex; and Cables: Nucliform.

Electromagnetic Pumps for Liquid Metals

SODIUM, sodium-potassium and lithium make a group of liquid metals which are likely to be used in nuclear energy applications, mainly as coolants where high rates of heat transfer are necessary at a high temperature. Bismuth is also likely to be useful, particularly in liquid fuel reactors, due to its ability to dissolve uranium and its low neutron absorption cross section. These two classes of liquid metal—the low density, viscosity and resistivity metals like sodium, and the high density, viscosity and resistivity metals like bismuth or mercury—usually require different methods of pumping. To meet these needs the British Thomson-Houston Company has developed various types of pump which are described here.

For bismuth, the D.C. conduction pump is generally most suitable. This pump in its most elementary form is shown in Fig. 1. It operates on the same principle as the electric motor, as symbolised by Fleming's Left Hand Rule: that is, if an electric current is established in a conductor and a field maintained at right angles to it, a force is developed perpendicular to both current and field. In the case of the electromagnetic pump the current is established in the liquid itself and a pressure is developed directly within it. D.C. conduction pumps suffer from the great disadvantage of inconvenient electrode current requirements—thousands of amperes at a level of one volt. For example, a 100-h.p. pump recently designed required 100,000 amps. at 2·5 volt; an efficiency of up to about 40% can be achieved at this size.

A.C. excitation of the conduction pump eases the current supply problem, but such pumps are less efficient, particularly in large sizes. They are very useful in small sizes, however, where an acceptable efficiency and power factor can be achieved, and liquids of both sodium and bismuth types can be successfully accommodated.

A further possibility in electromagnetic pumping is to induce the current in the liquid metal, and one of the most useful methods of doing this, particularly with metals like sodium, is to employ the induction motor principle. The spiral induction pump operates on the lines of the induction motor. As can be seen in Fig. 2, the construction is virtually that of a standard polyphase stator with a fixed core and a large air gap through which is wound several turns of a rectangular pipe containing the liquid metal. End rings are necessary in principle in establishing the desired axial electric current.

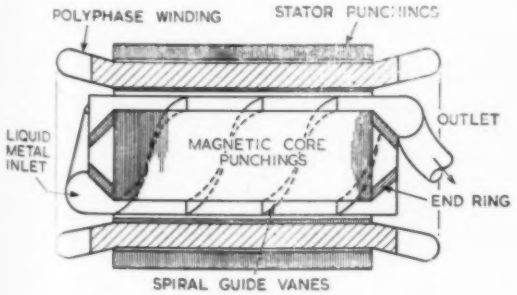


Fig. 2.—Sketch of spiral induction pump.

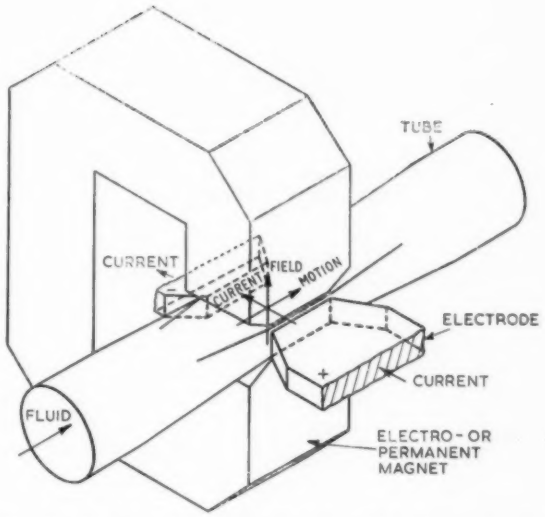


Fig. 1.—Sketch showing principle of D.C. conduction pump.

The field is of course radial, so the flow is circumferential, and the channel walls or guide vanes ensure that the liquid moves through the pump. Spiral induction pumps are specially suited to low-flow, high-pressure applications; 100 lb./sq. in. at 10 gal./min., and 80 lb./sq. in. at 40 gal./min. are ratings of pumps which have been designed, and it is in sizes such as these, say up to 10 h.p. output, where they have so far been most useful.

The linear induction pump operates on the same principles as a spiral induction pump, but the channel is straight and the travelling waves of field, flux, and current move axially. Two main forms of this pump exist. One is the flat form, where the channel is rectangular with side bars on either side, performing the same

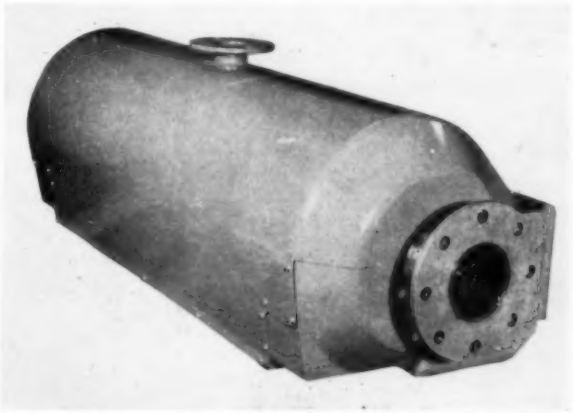


Fig. 3.—Annular linear induction pump which will pump 420 gal./min. of liquid sodium-potassium eutectic alloy at 175° C. and a pressure of 14 lb./sq. in.

function as end rings in the induction motor, and the winding is of the polyphase conventional type, though flat and on either side of the channel. An alternative form employs an annular channel enclosing a radially laminated central core, and being itself enclosed by a polyphase winding made up of pancake coils in radially laminated slotted punchings. A photograph of an annular pump for 420 gal./min. at 14 lb./sq. in. is shown in Fig. 3. The best efficiency recorded with this pump was 36·2% with 22/78 sodium/potassium at 175° C. The efficiency with sodium should be at least 41%.

The annular linear induction pump is suitable for much larger flow and pressure applications. Difficulties of accessibility of the winding can be avoided, either by splitting the winding so that it can be removed from the pipe, or by adapting a reverse flow form of construction where the fluid enters within a pipe inside the central core and reverses direction at the end to flow in the annular space between core and winding. The coils and slotted yoke can then slide over the free end.

An Unusual Fatigue Failure

By E. Wood

Many fatigue failures of engineering components examined in the laboratory can be attributed to features of design or misalignment during manufacture, but there seems to be little scope for such explanation in the failure of an engineer's hammer. The author puts forward a tentative explanation and invites suggestions.

AN engineer's hammer broken in service was recently submitted for investigation. The hammer was of the ordinary ball-peen type, weighing 3 lb., and the fracture was as shown in Fig. 1. The material of the hammer was B.S. 970 En.9 (0·55% carbon steel), selectively hardened on face and ball by quenching in water from molten lead at 840° C. The hammer had been in service for about five years, and, although it was reported to have had constant use, the surface of the striking face was in excellent condition and was, for practical purposes, unmarked.

As Fig. 1 shows, the fracture (which was quite clean and bright, though somewhat rubbed, when received) bore strong resemblance to the fracture of a circular shaft under rotating bending or repeated tensile (push-pull) stresses. The makers stated that it was the first time in their experience that a hammer had failed in this way; and experience in the laboratory of numerous fatigue failures of components ranging from 12 in. diameter shafts, through rolls, steam-hammer shafts and pistons, to split pins, $\frac{1}{16}$ in. diameter rollers, and 0·064 in. thick springs, suggested that it was difficult, if not impossible, to get a fatigue fracture on a hammer —however hard one hit with the hammer, the stress was simply not high enough to come within the fatigue range.

Under the binocular microscope the appearance shown in Fig. 2 was revealed. It could be seen quite plainly that the fracture had some features distinguishing it from more ordinary and straightforward fatigue:—

(*a*) There were three (and not two) distinct zones on the fracture.

(*b*) There was a distinct annular step about $\frac{1}{8}$ in. deep, and the high power of the binoculars showed a fissure or crack at the root of the step.

The zones took a roughly concentric form. The outer zone was coarse and irregular up to the step. The next, intermediate, zone was smooth and regular in texture, and appeared to be a true fatigue fracture. The inner zone was again rough and irregular, but not so much as the outer zone. These zones are marked *A*, *B* and *C* in Fig. 2.

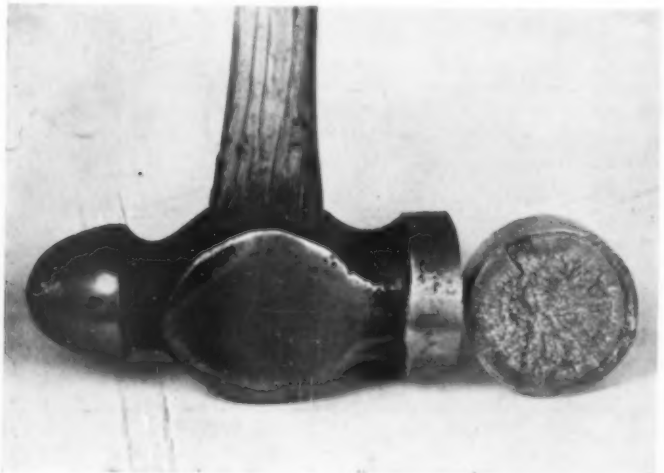


Fig. 1.—View of the hammer showing the location of the fracture.

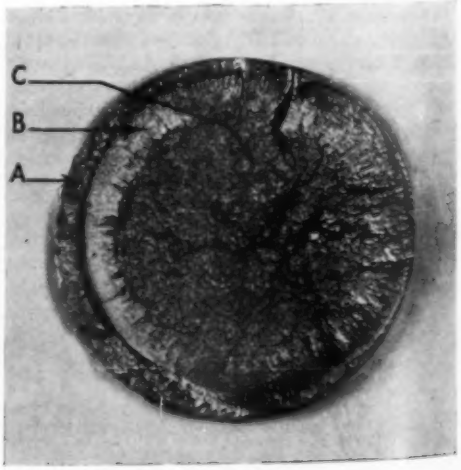


Fig. 2.—The appearance of the fracture surface. × 1¼ (approx.)

It was at first thought that, since the face of the hammer had been selectively hardened, the fracture might coincide with the plane of critical temperature due to the temperature gradient resulting from holding the face in the lead-bath, but hardness tests showed that this was not so. The fracture was $\frac{3}{4}$ in. from the face, and the plane of transition from fully hard (800/900 VPN) to 350/250 VPN was 0·4 in. from the face. The body of the hammer was uniform in hardness at 268–287 VPN.

The analysis was checked and found to be correct for En.9 material.

Microscopic Examination

Several sections were taken including the full depth from hardened face to fracture and the three zones of the fracture and the step. The following points were elicited from the microscopic examination :—

(*a*) The structure, where unhardened, was poor. It was overheated and coarse due to the stamping being in the " as-forged " condition.

(*b*) Zone *A* in Fig. 2 was burnt, as evidenced by the typical oxide rivers and white intergranular paths.

(*c*) The step and the fissure at its root were due to the burning.

(*d*) Zone *B* was due to fatigue.

(*e*) Zone *C* was produced suddenly, i.e., it was a brittle fracture due to sudden failure of the reduced section at the root of the notch created by the fatigue crack.

(*f*) The selective hardening of the face was effectively executed, resulting in a good fine-grained martensite merging through troostite and sorbite into the overheated interior. In the hardened portion the overheating had been cleared up.

Discussion

The history of the fracture can now be written. The hammer stamping was overheated generally and burnt (slightly but definitely) locally in the region of the fracture. Continued use broke down the burnt material on the outside, and a fatigue crack (or series of cracks) started concentrically, but at the inner boundary of the burnt material. The fatigue crack spread more or less concentrically until the reduced section and the very low notched bar strength due to the overheated structure resulted in total brittle failure.

What is still unexplained to the author's satisfaction is precisely what caused the fatigue stress at the root of the burnt parts. The fatigue crack, it must be remembered, progressed through overheated but not burnt material, and there is no reason to suppose that its fatigue strength would be drastically lower than that of well heat-treated steel. The only logical explanation which this laboratory has been able to put forward, and which it is fully realised is not at all convincing, is that the very hard face (its hardness should be 500/600 instead of the 800/900 recorded) allowed a heavier blow than normal without marking, and that the hammer thus actually had a hard life. It is easy to imagine that it was some craftsman's favourite tool for four years until one day a single blow resulted in final failure. A tensile stress at the plane of fracture could be accounted for by considering that on striking a blow the cylindrical portion behind the face assumes (elastically) a barrel shape, and thus puts a circumferential tensile stress about midway along the cylinder—where, in fact, fracture occurred. But it is the first fatigue fracture on a hammer that the author at any rate has ever seen, and he is quite prepared for it to be his last. Has anybody a better explanation than that tentatively suggested above?

To reassure metallurgists in general, and hammer-using metallurgists in particular, it should in fairness be added that since the failure normalising of the stamping after forging and stress relieving after hardening have been instituted.

Addendum

Since this article was written, a failure of a shaft in a steam hammer has been investigated. The fracture was very similar to that from this hand hammer, and discussion with the makers revealed their opinion that these failures are due to " reflected " stresses, i.e., the tension in a rod or solid cylinder which occurs as a reaction to the compression created by the blow.

Private information from the laboratory of a well-known engineering insurance company indicates that they have met several hand hammer failures resembling that described, but the author's laboratory is connected with a group of the best-known firms in the trade, and it is the first failure of its type recorded in their experience.

Swedish Plant for Large Welded Tubes

THE first plant in Scandinavia for the production of large-sized welded tubes, by the most modern methods recently began operating in Stockholm. Owned by the large steel structure manufacturers and contractors A.B. Bröderna Hedlund, the new workshop is designed for the manufacture of steel tubes of all dimensions from 300 mm. (1 ft.) and upwards in lengths of 8 m. (26 ft.) without transverse joints. The plant has an area of about 5,000 sq. m. (54,000 sq. ft.) and forms an extension of the company's large workshop in the Hammarby harbour in Stockholm. There is a keen demand for this type of tube in Sweden for water, steam, gas and other purposes. The company also counts upon exporting, in the first place to the other Scandinavian countries.

The tubes are made from plate of up to 15 mm. thickness. Having been cut, rolled and shaped, they are welded inside and outside by means of large welding machines. After being straightened, the tubes are radiographed and tested under pressure. In certain cases the tubes are joined into lengths of 16 m. by transverse welded joints, while in other cases they are provided with flanges. The firm of Bröderna Hedlund, which formerly produced welded tubes of shorter length, is at present supplying the new long-length types—which involve lower manufacturing and installation costs—for a great many purposes. The City of Stockholm is using them for a new 4,000 m. section of its long-distance water main from the Norsborg water works. Moreover, the Stockholm Electricity Works are installing 2,500 m. of such long-length tubes for conducting water at 120° C. from a district heating plant, while the city of Norrköping has ordered 4,000 m. of steel tubing for a similar heating plant. Other deliveries include tubes for superheated steam.

The equipment in the new workshop is largely of German design, while the building work has been executed by the Svenska Industribyggen, large Swedish contractors specializing in building industrial plants.

NEWS AND ANNOUNCEMENTS

The Iron and Steel Institute

Award of Medals and Prizes

THE following Medals and Prizes were presented at the Annual General Meeting of The Iron and Steel Institute at The Royal Institution, Albemarle Street, London, W.1, on the morning of Wednesday, 16th May, 1956, by the Retiring President, SIR CHARLES BRUCE-GARDNER, BT.

Bessemer Gold Medal for 1956.

To DR. C. SYKES, F.R.S. (Thos. Firth and John Brown, Ltd.) in recognition of his distinguished contribution to the study of alloy systems, particularly in the field of order-disorder changes and the effect of such changes on the physical properties of alloys.

Sir Robert Hadfield Medal for 1956.

To MR. H. MORROGH (British Cast Iron Research Association) in recognition of his distinguished contribution to the study of the metallography of cast iron, and for researches which resulted in the discovery of nodular iron and the improvement in the quality of cast iron.

Additional Williams Prize for 1954.

Jointly to MR. F. A. GRAY and MR. S. A. BROOKS (Appleby-Frodingham Steel Co.) for the paper on "An Investigation of Re-heating Furnace Design and Performance," of which they were the joint authors. (*J.I.S.I.*, 1954, Vol. 178, November).

Williams Prizes for 1955.

To MR. A. J. KESTERTON (The Steel Company of Wales, Ltd.) for his paper on "Some Starting and Operating Experiences at Abbey Melting Shop," presented before the Cleveland Institution of Engineers on 1st March, 1954, and published in the *J.I.S.I.*, 1955, Vol. 179, January.

To MR. R. WILCOCK (Samuel Fox & Co., Ltd.) for his paper on "The Operation of a 60-ton Arc Furnace at Samuel Fox & Co., Ltd." (*J.I.S.I.*, 1955, Vol. 180, June).

Ablett Prizes for 1955.

To MR. W. ERNEST (Samuel Fox & Co., Ltd.) for his paper on "Waste Heat Recovery related to the Generation of Electric Power." (*J.I.S.I.*, 1955, Vol. 179, March).

To MR. S. R. PHELPS (Guest, Keen & Nettlefolds, Ltd.) for his paper on "Flying Shears for Bars and Billets—Electrical Requirements." (*J.I.S.I.*, 1955, Vol. 181, November).

To MR. R. STEWARTSON (Guest, Keen & Nettlefolds, Ltd.), "Flying Shears for Bars and Billets—Mechanical Design Features." (*J.I.S.I.*, 1955, Vol. 181, November).

The Institution of Metallurgists

Annual General Meeting

THE Annual Luncheon of the Institution of Metallurgists took place on Tuesday, 15th May, 1956, at the Park Lane Hotel, Piccadilly, London, W.1., with the President, PROFESSOR F. C. THOMPSON, in the Chair. The principal speaker, the RT. HON. SIR DAVID ECCLES, K.C.V.O., Minister of Education, made reference to the part played by the Institution in the furtherance of technological education, and to the progress made by the Institution in its comparatively short history. Other distinguished guests were LORD KILLEARN, G.C.M.G., C.B., M.V.O.; SIR HUGH LINSTEAD, O.B.E., M.P.; VISCOUNT HINCHINGBROOKE, M.P.; SIR OWEN WANSBROUGH JONES, K.B.E., C.B.; and the RT. HON. A. G. BOTTOMLEY, O.B.E., M.P.

The Luncheon was followed by the Annual General Meeting, at which MR. G. L. BAILEY, C.B.E., Director of the British Non-Ferrous Metals Research Association, was elected President, and MR. J. MITCHELL, C.B.E. (a Director of Stewarts and Lloyds, Ltd., Corby), Senior Vice-President. MR. W. E. BALLARD (Director of Metallisation, Ltd., Dudley) and MR. A. J. MURPHY (formerly Professor of Industrial Metallurgy at Birmingham, now Principal of the College of Aeronautics) were elected Vice-Presidents, and DR. E. G. WEST became Honorary Treasurer for a further year. The newly elected members of the Council are MR. W. E. BARDGETT (United Steel Cos., Ltd., Sheffield), MR. E. J. BRADBURY (The Mond Nickel Co., Ltd., Birmingham), DR. N. P. INGLIS (I.C.I., Ltd., Metals Division, Birmingham), and MR. F. H. KEATING (I.C.I., Ltd., Billingham Division, Co. Durham).

The new President, in his Presidential Address (a report of which appears elsewhere in this issue), discussed the important work of the Institution in promoting the interest of metallurgists, and considered the future prospects for metallurgy, potential metallurgists, and the Institution, of which the total membership is now 3,331. He felt that metallurgy offered a most attractive and exciting opportunity for new development and expansion, in spite of some competition with other materials. He went on to consider the Institution's qualifications, and the type of training which a metallurgist required, particularly emphasising the need of broad training in the humanities and basic science, as a preliminary to specialist instruction in metallurgy.

Bessemer Centenary

IN co-operation with the Science Museum, South Kensington, the British Iron and Steel Federation is to create a new ferrous metallurgical display in the Museum to commemorate Sir Henry Bessemer, for which purpose the sum of £50,000 has been allocated. It is hoped the gallery will be completed within three years. Preliminary plans for this exposition are being prepared in consultation with the Museum Authorities. The present space of the iron and steel section is 2,800 sq. ft., but even this is partly intermingled with the exhibits of the non-ferrous metallurgical industries. As part of their general scheme of re-organisation, the Museum Authorities hope to make available 3,500–4,000 sq. ft. in a self-contained and separate section. The Minister of Education has expressed his gratitude to the industry for showing their interest in the Museum in so practical a way.

PERA Director Visits Canada and U.S.A.

DR. D. F. GALLOWAY, Director of Research, PERA, is at present on a tour of Canada and the U.S.A. His principal engagement is to give the Calvin W. Rice Memorial Lecture to the American Society of Mechanical Engineers on Tuesday, 19th June, at Cleveland, Ohio. Dr. Galloway's subject will be "Production Engineering

Research and its Practical Application in Britain." On the following day, Wednesday, 20th June, Dr. Galloway will give a second talk, again to the Semi-Annual Meeting of the A.S.M.E., entitled "Some Experiments to Determine the Influence of Various Factors on Drill Performance."

At the Annual Meeting of the Engineering Institute of Canada, held in Montreal on Wednesday, 23rd May, Dr. Galloway gave a general talk on the activities of PERA. This was a joint meeting between the A.S.M.E. and the Engineering Institute of Canada. Dr. Galloway's tour, which ends on the 23rd June, includes visits to a number of engineering companies and research centres.

Institution of Mining and Metallurgy Awards

THE Council of the Institution of Mining and Metallurgy have announced the following awards :—

The Gold Medal of the Institution has been awarded to Dr. J. A. BANCROFT, in recognition of his long and distinguished services to the mineral industry in Southern Africa, and in the advancement of the science and practice of economic geology.

Honorary Membership of the Institution has been conferred on COL. THE HON. C. A. BANKS, C.M.G., in recognition of his services to the mining industry, with particular reference to his pioneering work in the introduction of air transport for the equipment of poorly accessible mineral properties; on THE RT. HON. VISCOUNT CHANDOS, P.C., D.S.O., M.C., for his services to metallurgical industries in the United Kingdom; and on Mr. G. F. LAYCOCK, M.C., Past-President of the Institution, for his services to the mineral industry and to the Institution.

"*The Consolidated Gold Fields of South Africa, Limited*" *Gold Medal* for the Session 1954–55 has been awarded to Mr. J. F. G. R. HEYWOOD, for his paper entitled "Pressure Manifestations at Great Mining Depths on the Witwatersrand" (*Trans. Inst. Min. Metall.*, Vol. 64); and "*The Consolidated Gold Fields of South Africa, Limited*" *Premium of Forty Guineas* for 1954–55 to Dr. J. J. BRUMMER, for his paper entitled "The Geology of the Roan Antelope Orebody" (*Trans. Inst. Min. Metall.*, Vol. 64).

The "*William Frecheville*" *Student's Prize* for the Session 1954–55 has been awarded to Mr. F. M. VOKES and Mr. W. G. JEFFERY, conjointly for their paper entitled, "The Geology of New Consols Mine, Cornwall," (*Trans. Inst. Min. Metall.*, Vol. 64).

Vicker's Canadian Acquisition

VICKERS, LTD., announces that it has acquired a controlling interest in Canadian Vickers, whose works and shipyards are at Montreal. This enables Vickers to re-enter Canada in the company which it itself founded in 1911 and operated until 1927. Canadian Vickers has an outstanding position in Canada in the field of general engineering and shipbuilding, and will now be reinforced by the technical resources and experience of the Vickers Group.

Vickers attaches great importance to retaining a strong Canadian element in the company shareholding, and it is an essential part of the transaction that at least 45% of the stock remains in the hands of existing shareholders. Mr. J. E. Labelle, Q.C., O.B.E., and Mr. O. H. Barrett, O.B.E., present Chairman and President respectively of Canadian Vickers, will continue in office. Representatives of Vickers, Ltd., will join the Board in due course.

The Institute of Metals

New Fellow Elected

DR. R. A. WILKINS, Vice-President, Research and Development, Revere Copper and Brass Inc., Rome, N.Y., U.S.A., has been elected a Fellow of the Institute of Metals in recognition of his outstanding services to the Institute, in particular as Corresponding Member to the Council in the United States. Election to the Fellowship is the highest honour bestowed for services to the Institute itself and Fellows are limited in number to twelve. Dr. Wilkins is the first member resident outside the British Isles to be elected to the Fellowship.

Railway Modernisation Contracts

THE British Transport Commission have placed contracts for 1,500 mineral wagons and 166 power equipments for diesel shunting locomotives with the following manufacturers: The Butterley Co., Ltd. (1,000 16-ton mineral wagons); Derbyshire Carriage & Wagon Co., Ltd. (500 16-ton mineral wagons); The General Electric Co., Ltd. (45 power equipments for diesel shunting locomotives); and The English Electric Co., Ltd. (121 power equipments for diesel shunting locomotives). The locomotives, for which the diesel power equipments are required, will be built in the British Railways workshops at Derby, Crewe and Darlington for allocation to all regions.

U.S. Titanium Price Cut

TITANIUM METALS CORPORATION of America announced last month, a reduction of 20c. per pound in the price of titanium sponge metal, bringing the price down to $3·25. This is the fourth price cut initiated by T.M.C.A., in a 14 month period, and is part of an aggressive programme to make this new engineering metal fully competitive with certain steels, aluminium and magnesium. At the same time, the price of all mill products —sheet, strip, billet, bar, extrusions, and wire—were lowered about 6%, with reductions ranging from 65c./lb. to $1·00/lb. for products such as sheet or strip. The rapid series of price reductions is related to the cost improvements achieved by volume production. Technological advances in sponge production, utilisation of scrap, and continuous rolling are also contributing to better costs. Each price reduction has generated an increasing volume of non-military applications. Within several years, it is expected that urgent defence requirements will be supplemented by sizeable and diverse applications throughout the chemical processing industries, civilian aircraft, marine, pulp and papermaking, atomic power and pharmaceutical industries.

Training in Automatic Welding

A SPECIAL training course for welding operators engaged on the Unionmelt Submerged-Arc welding process will be held by Quasi-Arc, Ltd., at their Gateshead works from 2nd–6th July. Theoretical instruction will be given on welding procedures, joint designs and preparations, welding materials, weld faults, care and mainten-

ance of machines and applications of automatic welding. Practical instruction will include the operation of machines for single and multipass butt and fillet welds, and demonstrations of the effects of variation in speed, current, and voltage, and other factors which affect good welding results. Further details and enrolment forms can be obtained from Quasi-Arc, Ltd., Bilston, Staffs.

Huntington Heberlein Sinter Plants

HUNTINGTON, HEBERLEIN & CO., LTD., a company of the Simon Engineering Group, report that since the beginning of 1955 they have received orders, directly or through main contractors, for nine Dwight-Lloyd continuous sintering plants and associated equipment in Britain and three overseas countries.

These nine plants will have an aggregate capacity of 14,600 tons of sinter per day. They comprise three in Britain for Barrow Ironworks, Dorman Long and the Consett Iron Company; one in South Africa for ISCOR; three in France and the French Union for Le Nickel, De Wendel and Société Métallurgique de Normandie; and two in Belgium for Cockerill-Ougrée and Forges de la Providence. Most of the export contracts were secured against keen competition, especially from Germany.

It is interesting to note that most of the material, apart from highly specialised equipment, for the French and Belgian plants will be manufactured on the Continent, to engineering designs and technical know-how provided by Huntington Heberlein: the fees they will receive are an example of how exports of British brains and experience can earn foreign exchange with little or no demand on Britain's over-burdened resources of materials and manual labour.

Alloy Castings Venture

DEWRANCE & CO., LTD., the well known makers of boiler mountings and piping valves, announce the formation of a Special Alloys Division. This Division will handle "Endewrance" High Alloys, which are particularly suitable for components in industry where heat, abrasion, corrosion and erosion resistant qualities are necessary. These alloys can be supplied as machined or unmachined castings, or in the form of welding rods, and full details can be obtained from the Division, together with a copy of a new publication No. 682 describing these alloys. The Division also handles the Company's Patent T.L.B. metal powder deposition process and powdered metals suitable for high temperature brazing. Dewrance are working in close collaboration with Coast Alloys, Inc., Littleferry, New Jersey, for the development and sale of high alloy castings in this country, the Commonwealth and a number of European countries.

New British Oxygen Works for Dundee

THE BRITISH OXYGEN CO., LTD., has supplied compressed oxygen from a works in the harbour area of Dundee for a considerable number of years. It was recently found that the facilities were inadequate for the volume of business, and a new works has now been built on a six acre site in the Milton of Craigie area of Dundee. This is a well laid out modern works capable of compressing 500,000 cu. ft. of oxygen per week into cylinders for distribution to customers along with other industrial gases which they require. It was also decided to produce dissolved acetylene in Dundee, and the new works includes a plant for this purpose with a capacity of 350,000 cu. ft. per week. Improved facilities are also included in the form of stores for new equipment.

New Steel Warehouse

SANDERSON BROTHERS AND NEWBOULD, LTD., have recently augmented their stocking facilities for tool and alloy steels by the erection of a new steel warehouse having a floor area of 12,000 sq. ft. The new warehouse is equipped with two 3-ton capacity overhead cranes, circular cold sawing machines, hacksawing machines and inspection benches. Layout is designed to facilitate the inspection, cutting to length and making up for despatch of consignments of steel for both the home and export trade. It is part of a rebuilding and modernisation programme being undertaken by the Company.

Radiovisor Removal

RADIOVISOR PARENT, LTD., manufacturers of photo-electric and electronic controls, have recently moved their complete organisation from 1 Stanhope Street, N.W.1, to the new factory at Stanhope Works, High Path, London, S.W.19. The necessity for enlarged manufacturing facilities due to the increasing use of Radiovisor photo-electric controls, has been accentuated by the trend towards automation in recent years. In addition, the present-day scrutiny of fuel costs by management has resulted in an increased demand for Radiovisor industrial combustion control equipment as an aid to fuel efficiency. The new factory provides 30,000 sq. ft. of manufacturing space on one floor.

Successful Mechanical Handling Exhibition

THE 5th Mechanical Handling Exhibition, which was held at Earls Court in May, was the most successful to date. Buyers came from more than 80 countries, and the attendance was considerably better than that of any previous year. The Exhibition—which is organised by *Mechanical Handling*, an Associated Iliffe Press Journal—is the largest of its kind in the world, and is held every other year.

New London Offices for Compoflex

To cope with greatly increasing business, the Southern Flexibles Centre of Compoflex Co., Ltd.—and the company's head office and sales staffs—are moving from Grosvenor Gardens to larger premises at 23–25, Northumberland Avenue, London, W.C.2 (Tel.: TRAfalgar 7800). The new address will come into effect from July 2nd.

International Machine Tool Exhibition

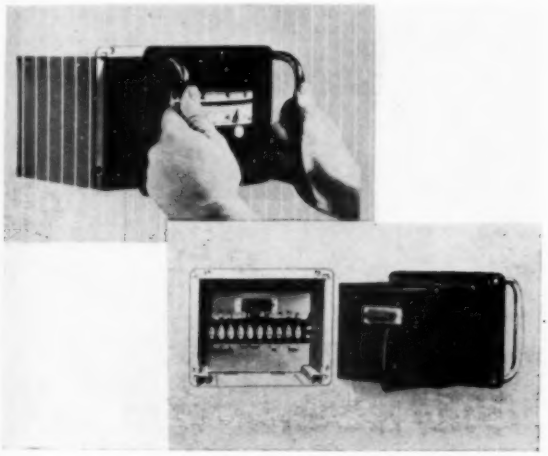
THE International Machine Tool Exhibition will be held at Olympia, London, from Friday, June 22nd, to Friday, July 6th, 1956, inclusive. The daily opening hours—Sunday excepted—will be from 9.30 a.m. to 6 p.m., and the admission charge will be 3s. 6d. Exhibits will include metalworking machine tools, woodworking machinery, engineers' small tools, gauges and measuring equipment, presses and power hammers, and heat-treatment plant.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Plug-in Instrument Housing

WEST INSTRUMENT, LTD., have introduced a new accessory whereby continuous operations involving temperature control are safeguarded from risk of shut-down. It is a plug-in instrument housing, designed for application on continuous processing where qualified maintenance staff are not generally available on all shifts, and where, in the event of instrument lapse, the machine would normally be out of production. With this new accessory, unskilled labour can promptly replace the complete temperature controller and assure production continuity.



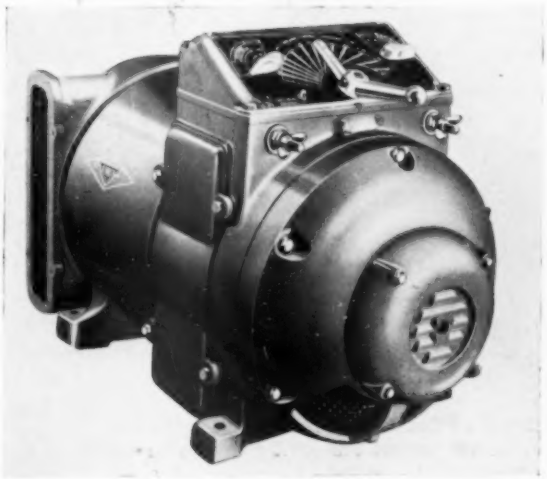
West's new accessory consists of two units: one is the complete temperature controller with hand grips and mounted self aligning plug; and the other section is the housing which receives the first unit and provides the matching socket and external wiring terminal block. Gold plated contacts, wiping action, and spring loading in the plug and socket assure trouble-free operation. This assembly may be surface or flush mounted, and in order to replace an instrument the operator simply slides out one instrument and slides in the other. Replacement can be effected in less than five seconds, without tools or recordable temperature variation.

West Instrument, Ltd., 52 Regent Street, Brighton, 1.

Dynex Welding Generator

THE Murex Dynex welding generator has been designed from the outset to have special advantages for welding purposes, and is suitable not only for D.C. metal arc welding, but also for other processes such as argon arc welding. Furthermore, it has been designed so that it can be supplied as a motor generator equipment, and so that it can be incorporated into all Murex engine-driven equipments.

A new and unique principle of current control gives infinite current adjustment between maximum and minimum values at a practically constant open circuit voltage. When necessary, the open circuit voltage can also be infinitely varied between maximum and minimum values to meet the needs of special applications. The machine is twice as fast in voltage recovery as a conventional type of equipment owing to the laminated construction and the special design of its field components.



A polarity changeover switch is fitted, and the need for instruments has been eliminated by a clearly and accurately calibrated indicator plate. In the case of motor generators a simple push button starter is incorporated. A thermal type overload protective device is also incorporated in the motor generator sets.

The Dynex generator (Type DX002) has a welding rating of 9–14 kW. Its output is infinitely variable from 20 to 400 amps., and its open circuit voltage from 70 to 90 volts. The figures for the Type MDX041 motor generator are 15–200 amps. at 25 volts for continuous hand lweding, and up to 300 amps. at 30 volts for intermittent hand welding, with an open circuit voltage variable between 70 and 90 volts. The 300–450 amp. Dynex motor generator (Type MDX002) has an output infinitely variable from 25 to 300 amps. at 30 volts for continuous hand welding, and up to 450 amps. at 35 volts for intermittent hand welding, with the same open circuit voltage range as the others.

Murex Welding Processes, Ltd., Waltham Cross, Herts.

Electronic Thermostat

THE latest model of the Fielden electronic precision thermostat has, as the temperature sensing element, a high-grade rapid response resistance bulb. This forms one arm of an A.C. bridge, the out-of-balance of which is amplified by a high-gain, phase sensitive amplifier, and the output from this operates a relay.

The setting-up consists, merely, of connecting to the A.C. mains and turning the calibrated dial on the front of the instrument to the desired temperature. No further attention is necessary, unless it is required to

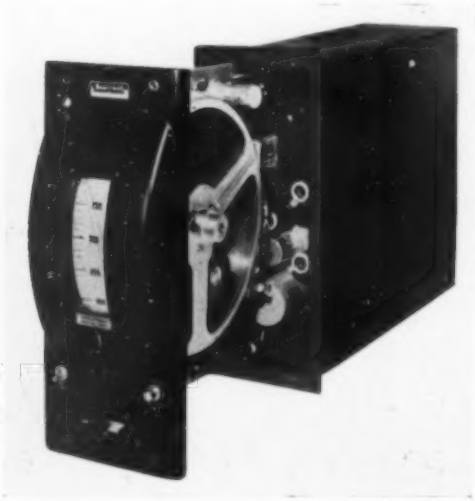
alter the control point, and a change of 0·1° C. either side of the pre-set temperature value on a 100° C. range is sufficient to operate the relay for alarm or control action. Two coloured indicating lamps are fitted on the front of the case.

The instrument is being marketed in ten standard ranges up to 500° C. or 932° F., and the incorporated relay is rated at 5 amps., 250 volts, 50 cycles non-inductive load, or 1 amp. 250 volts D.C. In its present form, with a $6\frac{3}{4} \times 7\frac{3}{4} \times 4\frac{1}{2}$ in. die cast aluminium alloy case, it is a robust piece of equipment, equally suitable for research or industrial use.

Fielden Electronics, Ltd., Paston Road, Wythenshawe, Manchester.

Vertical Scale Indicators

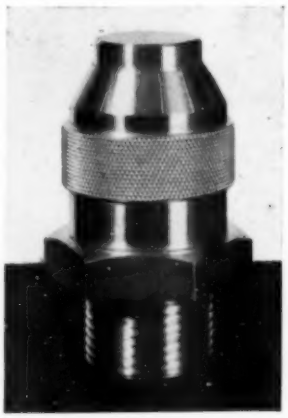
With a view to space saving on instrument panels, Honeywell-Brown have recently introduced the Electronik vertical scale precision indicator. With face dimensions of $6\frac{1}{4} \times 15\frac{3}{8}$ in., five of these instruments can be mounted in the same panel space needed for two circular scale models. The new indicator incorporates the continuous balance circuit common to all Electronik instruments, and the sensitivity is $\frac{1}{32}$% of scale span: the accuracy is within ± 0·2% of scale span. The rotating scale has a length of $28\frac{5}{8}$ in., of which 5 in. are visible through the window. A twin hairline index prevents parallax errors. For inspection and service, the indicator chassis can be slid out from the front without stopping operation of the instrument.



Honeywell-Brown, Ltd., Perivale, Middlesex.

Speed Regulators

Five new speed regulators have now been added to the Baldwin range of pneumatic equipment, the bore sizes being $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ and 1 in. In most pneumatic installations, some means of controlling the speed of movement of the air cylinder is required. Furthermore, it is usually necessary for the speed to be different in each direction of movement. Baldwin speed regulators have been designed to screw into the exhaust ports of the directional control valve, thereby throttling the escape of air from the exhausting end of the air cylinder. This method of speed control is to be preferred in all cases where steadiness of motion is important. These regulators are very compact and are made of nickel-plated brass. A friction device prevents the micrometer adjustment from being disturbed by vibration. The maximum working pressure is 150 lb./sq. in.



Baldwin Instrument Co., Ltd., Brooklands Works, Dartford, Kent.

Welding Positioners

Quasi-Arc, Ltd., have announced a new range of welding positioners specially designed to give robust service in any fabricating shop. The range includes a 1 cwt. bench type positioner and 10 cwt. and 1 ton floor type positioners, all having rotatable turntables which can be tilted through 135° from horizontal. The frames are of all-welded construction to enable them to withstand rough usage. These positioners are particularly recommended for hand welding operations, where the more expensive type of manipulators are not warranted. They enable the fabrications to be positioned so that all the welding can be done downhand, and so achieve maximum economy in welding.

Quasi-Arc, Ltd., Bilston, Staffs.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

JUNE, 1956 Vol. LIII, No. 320

A New Spectroscope for Visual Analysis

By R. H. Tyas, A.Met., L.I.M.

Sheffield Laboratories, British Iron & Steel Research Association.

Although, using the method of homologous line pairs, a wide variety of metals and alloys can be identified and analysed by the Fuess Metal Spectroscope, considerable experience is required in order to achieve suitable accuracy. Use of the recently developed photometer attachment, however, results in a remarkable improvement in speed, accuracy, and the ease with which the operator acquires additional skill. Possible uses of the instrument include the control of scrap, the sorting and grading of metals and alloys, checking of finished products and, to a limited extent, the replacement of certain determinations in routine chemical analysis.

A VISUAL spectroscope, manufactured by the firm of R. Fuess of Berlin* for the analysis of metals and alloys, has been tested in the laboratories of the British Iron and Steel Research Association. The equipment, seen in Fig. 1, consists of the following items.

(1) A high dispersion spectroscope covering the wavelength region 3900–7000 Å. Although of very compact design the resolving power and dispersion correspond to those of a three-prism optical system.

(2) Two sample tables of the Petry type, enabling the spectrum of an unknown sample to be compared directly with that of a known standard.

(3) A photometer attachment known as the Spectrolux, allowing measurement of the relative intensity ratios of selected spectrum lines.

(4) Guide rods for the optical alignment of the two arc discharges with respect to the spectroscope.

(5) An adjustable resistance for regulation of the arc current within the range 3–10 amperes.

(6) A source unit of modified Pfeilsticker design, providing an intermittent A.C. arc between the sample and a disc electrode of copper or iron.

A number of instruction manuals are supplied, which contain details of the operation and adjustment of the equipment, analytical techniques, charts and tables of homologous line pairs, and calibration graphs.

The sample is arced against a counter electrode of copper or iron, and the spectrum examined visually by means of the spectroscope. The equipment has been designed to allow the development of analytical procedures for a wide range of metals and alloys. Selection of a particular spectrum line is made by means of a drum calibrated in arbitrary units, conversion of these units to wavelength being made on a standard graph. Only during the development of an analytical procedure is such a conversion necessary, since during routine analysis a line pair is selected merely by setting the

* Supplied by Surfard Ltd., Abbey House, Victoria Street, London, S.W.1.

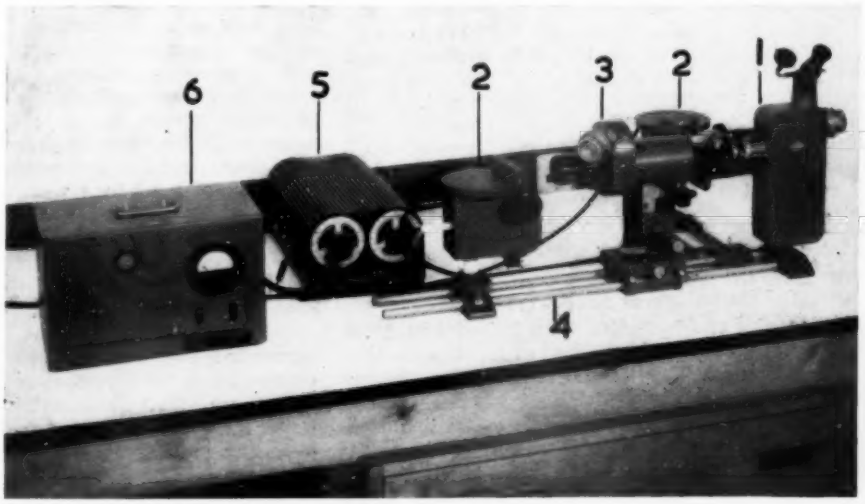
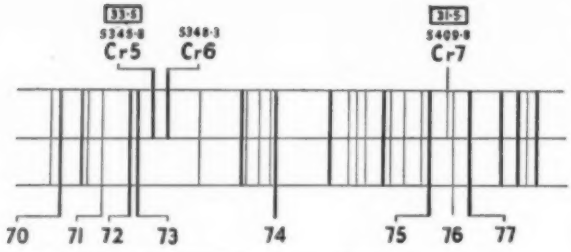


Fig. 1.—A general view of the Fuess Metal Spectroscope and its accessories.



0·3%	Cr5=71			4%	Cr5=70	Cr6=73	Cr7=75
0·7%		Cr6=71		5%	Cr5=77		
1%	Cr5=72		Cr7=76	7%	Cr5=75		
1·5%	Cr5=76			10%	Cr5=74	Cr6=70	
2%	Cr5=73			12·5%		Cr6=77	
2·5%		Cr6=72	Cr7=77	15%		Cr6=75	
3%		Cr6=76		25%		Cr6=74	

Fig. 2.—An extract from the illustrations of the spectrum.

measuring drum to the appropriate value stated in the manual.

In this way, other metal spectra and unknown impurity lines can be identified, and suitable analytical procedures established. The comparison sample table greatly facilitates this work by producing, adjacent to the unknown spectrum, a second spectrum of the element or alloy to be identified. A satisfactory procedure is to arc on the comparison table a sample of the base material containing no impurities or alloying elements, whilst at the same time arcing on the analysis table a sample of the alloy under investigation. The lines of the base element are present in both spectra, whereas the lines of the impurities or alloying elements appear only in the analysis spectrum and can, therefore, be recognised immediately. The effectiveness of this latter procedure in identifying spectrum lines is partly responsible for the ease with which the operator acquires experience.

Qualitative Analysis—The Identification of Metals and Alloys

If the equipment is used without the photometer attachment, much rapid qualitative analysis can be carried out, together with a certain amount of semi-quantitative analysis. Over the entire visible region, the spectra of steel, cast iron, copper, and aluminium alloys have been investigated by the manufacturer, and detailed working instructions together with graphical illustrations of the spectrum have been provided, all useful element and iron lines being identified and numbered. A chart is provided whereby more than fifty elements giving rise to spectrum lines in the visible region can be identified and, with an adequate supply of materials to provide comparison spectra, positive proof of such identification can be obtained.

Semi-Quantitative Analysis—The Method of Homologous Line Pairs

The method of analysis when using the equipment as a simple spectroscope is the method of homologous line pairs. One or more lines of the impurity or alloying element are compared with neighbouring lines of the base metal. When impurity and base metal line have the same brightness, a certain concentration of impurity is indicated, these concentration values, together with the spectrum lines used, being presented in the form of tables. Approximately forty such tables are contained in the instruction manual, and all lines are clearly identified from the illustrations, an extract from which is shown in Fig. 2.

Although this method of analysis is accurate when carried out carefully and systematically, it is obviously necessary for the operator to familiarise himself with the line pairs used and to be able to recognise, immediately, a small group of lines present within a large series. Thus, if an operator is to carry out semi-quantitative analysis of a wide variety of metals and alloys, his period of training may be unduly long. This disadvantage has, to some extent, restricted the application of visual spectroscopes in Great Britain, although this is not so in Europe, where about 1000 Fuess Metal Spectroscopes are used in all branches of industry, in many cases without the advantage of the recently developed photometer attachment.

Quantitative Analysis—The Photometer Attachment

The aforementioned disadvantage of the simple spectroscope completely disappears with the use of the photometer attachment. Fig. 3 shows the optical layout of the attachment, illustrating the method of analysis and the form of calibration graph used. Light from the arc is split into two beams, which are polarised in mutually perpendicular planes by means of two fixed polarising filters. Interposed in both beams is a third polarising filter that can be rotated through 90° by means of a calibrated drum, reading directly the angle setting of the filter. When set to an angle of 45°, both spectra are of equal intensity. Rotation of the filter then causes the intensity of one spectrum to increase while the other decreases, or vice-versa, according to the direction of rotation. Thus, when the element line is viewed in one half of the spectrum and the comparison line in the other, rotation of the main polarising filter enables the two lines to be adjusted to equal intensity. The drum reading, which corresponds to intensity ratio, is noted and the percentage content obtained from the manufacturers calibration graph.

The outstanding advantage of this latter procedure is that a single line pair can be used over a wide range of concentration, thus reducing the number of line pairs to be memorised. It now becomes necessary to recognise only two spectrum lines in order to determine one element, whereas the method of homologous line pairs often requires recognition of up to a dozen lines. While the overall intensity of the spectrum decreases when the photometer is interposed in the optical system, this is more than offset by the superior accuracy and ease of operation. Briefly, the procedure is as follows. The spectroscope is set for the required element, the sample placed on the specimen table and the arc switched on. The photometer control is rotated and the selected two lines are adjusted to equal brightness. The photometer reading is noted and the two lines again adjusted to equal brightness. Up to four readings can be taken in approximately one minute, and the determination completed by converting the mean reading to concentration on the appropriate calibration graph. With the photometer attachment, routine analysis does not require the use of the second specimen table. Only during the initial training period of the operator does the second specimen table once again prove invaluable.

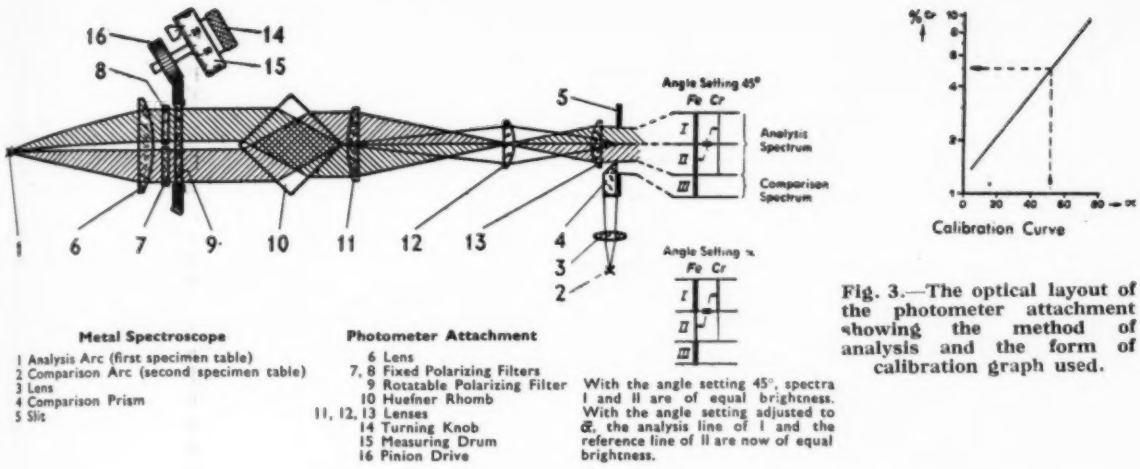


Fig. 3.—The optical layout of the photometer attachment showing the method of analysis and the form of calibration graph used.

Calibration Graphs

Twenty-four calibration graphs were supplied with the photometer attachment, and other graphs are in preparation. The concentration ranges covered are shown in Table I. Twelve calibration graphs for steel analysis were established independently, using B.I.S.R.A. spectrographic standards, and after a large number of tests had been carried out, both in the author's and the manufacturer's laboratory, all but two of these graphs agreed closely with those printed in the instruction manual. The B.I.S.R.A. graphs for nickel and molybdenum, which lay close by, but parallel to the Fuess graphs, were both of necessity prepared using lines that were not easy to compare. In the case of nickel the line is weak, and from the various graphs obtained it is evident that a systematic error can arise, whereby two operators may produce perfectly satisfactory calibration graphs, which, although they do not coincide, do enable the operator to achieve satisfactory analytical results. One of the two molybdenum lines in use is very close to an intense iron line, and once again a systematic error may arise due to the distracting effect of the nearby iron line. The alternative molybdenum line is, however, quite satisfactory, once the operator has accustomed himself to the low intensity of that particular region of the spectrum.

The determination of silicon has proved a very difficult problem, and all attempts by the manufacturer to achieve a reliable visual method have failed. The silicon lines available for visual analysis lie in a region of the spectrum where the human eye is relatively insensitive, and, to complex the problem, they are spark lines, the excitation of which is not possible with the simple Fuess source unit. Attempts are being made to modify the source unit in order to obtain a true spark-like discharge and sufficient line brightness to permit the photometric determination of silicon.

TABLE I.—RANGE OF CONCENTRATIONS COVERED BY THE PHOTOMETER ATTACHMENT.

Element	Concentration Range %		
	Steels	Cast Iron	Al-Alloys
Co	2 —50	—	—
Cr	0·03—34	0·03—1·2	—
Cu	0·1 — 3	0·1 —3	0·2 — 5·5
Fe	—	—	0·15— 3
Mg	—	0·03—0·2	0·16—12
Mn	0·1 — 6	0·1 —2·2	0·10— 2
Mo	0·05—15	—	—
Ni	1·4 —36	—	—
Ti	0·08— 1	—	0·25— 3
V	0·15— 8	—	—
W	1 —28	—	—
Zn	—	—	0·15— 3

The only reliable method of determining silicon is to use the camera attachment to the Metal Spectroscope and the arc line of silicon at 3905 Å. Evaluation of the densities can be carried out by means of a standard paper density scale, thus dispensing with the need for a micro-photometer. A coefficient of variation of $\pm 10\%$ can be achieved but, when used with the camera attachment, the Metal Spectroscope is no longer an instrument for rapid analysis.

Of the four graphs supplied for cast iron analysis, only the magnesium graph was checked, and this agreed closely with the Fuess graph. Using a series of aluminium alloy standards, satisfactory graphs were obtained for magnesium and manganese, but these did not quite coincide with the Fuess graphs. It was only possible to check odd points on the graphs for iron, copper and titanium, and considerable scatter was evident. The reproducibility obtained on these alloys was not as good as that obtained on steel. This was thought to be due, firstly, to the standards, which were of small bulk and tended to overheat: other aluminium samples of larger bulk gave better reproducibility. Secondly, in the analysis of aluminium alloys, the spectrum of the iron counter-electrode is used as the internal standard, thus allowing irregular variation of the element line with respect to the comparison line. In the analysis of steels, both element and comparison line originate in the sample under test, and hence small variations in the arc discharge affect both lines to the same extent, resulting in only small changes in the ratio of the two lines. The determination of lead and tin in impure aluminium was investigated, but sensitivity proved low, the limit of detection being approximately 0·1% for lead and 1·0% for tin. The reproducibility of the lead determination was poor due to the only available lead line being a spark line of low intensity.

Accuracy and Experience

The two most important features of the photometer attachment are the ease with which the operator acquires experience, and the accuracy of the results obtained. With the aid of a set of training samples supplied by the

TABLE II.—RESULTS OF SHORT TERM REPRODUCIBILITY TESTS.

	Cr	Mn	V
Chemical Mean (%)	0·34	0·60	0·19
Spectrographic Mean (%)	0·32	0·62	0·19
Range (%)	0·29–0·35	0·55–0·68	0·17–0·22
Standard Deviation* (%)	0·022	0·044	0·017
Coefficient of Variation* (%)	±6·9	±7·1	±8·9
Mean Coefficient of Variation (%)		±7·6	

* See Appendix.

manufacturer, operating experience with the photometer is acquired very rapidly, and much useful analysis can be carried out after only one week's experience. To a great extent this is due, firstly, to the small number of line pairs to be memorised, and, secondly, to the design of the instrument, which is both simple and comfortable to operate, thus reducing operator fatigue to a minimum. This latter point is extremely important where visual spectroscopic analysis is carried out on a large scale. It should be mentioned here that the set of training samples supplied by the manufacturer is intended for training purposes only, and is not for the purpose of checking the graphs.

By dispensing with the interpolation that is part of the method of homologous line pairs, the photometer shows an appreciable increase in both the speed and accuracy of analysis. After only one week's experience with the instrument, the author carried out a short term reproducibility test. In order to obtain an accurate analysis, four repeat readings were taken on one sample over a period of approximately one minute. Ten such determinations of chromium were made and a coefficient of variation of $\pm 9{\cdot}7\%$ was obtained. Further investigations were later carried out, and after a total of four or five weeks intermittent experience with the photometer attachment, reproducibility tests were made on the determinations of chromium, manganese and vanadium, and the results shown in Table II were obtained.

It is not anticipated that any further experience will substantially reduce the mean coefficient of variation below $\pm 7{\cdot}6\%$. The figure agrees closely with that obtained from the more thorough test carried out by the manufacturer, when several observers working on a number of instruments made a total of 1846 measurements with 12 line pairs, and obtained a mean coefficient of variation of $\pm 8\%$.

It is impossible here to make a detailed comparison between the accuracy of determinations on the Metal Spectroscope and the accuracy obtained on conventional spectrographic equipment. Due to the versatility of the photographic procedure and the elaborate equipment at present in use, coefficients of variation of ± 1–3% are common, although they do rise to ± 5–10% for the more difficult determinations. In a recent paper by the Spectrographic Analysis Sub-Committee of B.I.S.R.A.[1] the coefficients of variation for vanadium, molybdenum, cobalt, tin and titanium were obtained, using a spectrographic procedure and source units similar in principle to the Fuess source unit. The mean of the coefficients of variation obtained is $\pm 6{\cdot}7\%$, and it is apparent from the range of the results quoted that, where residual elements in concentrations of $0{\cdot}01$–$0{\cdot}20\%$ are being determined, the accuracy of spectrographic and visual spectroscopic procedures are comparable. The comparison, however, applies only to a restricted range of elements and concentrations.

Conclusions

With operational experience acquired so rapidly, it is possible to put the equipment into routine operation within one week of installation. Depending on the accuracy required, the speed of analysis varies from 15–60 seconds for one element. The speed with which one can carry out repeat tests of a similar nature is so rapid that the foot switch supplied by the manufacturer is essential. Offering rapid and reasonably accurate analysis of a wide range of materials, its application will continue to spread as new line spectra are investigated.

As a means of production control in the metallurgical industry the Fuess instrument has many possibilities. It can be used to control scrap and other materials used daily in production, to sort and grade stocks of materials, and to check the analytical specifications of finished products. The sorting of materials is greatly facilitated by the use of the comparison table, which, among other things, serves to refresh the memory of the operator who uses the equipment infrequently. Much time and effort can be saved when checks are carried out on the spectroscope prior to chemical analysis, and in certain instances residual elements and alloying elements of low concentration can be determined with an accuracy comparable with that of routine chemical analysis. Costing approximately one quarter the price of conventional spectrographic equipment, and covering a wide variety of metals and alloys, it could be operated in industry as a very efficient and useful tool.

Acknowledgments

The author wishes to express his thanks to the firm of R. Fuess for permission to reproduce extracts from their catalogues, in particular to Dr. K. D. Mielenz for helpful advice and co-operation, and to Messrs. Surfard, Ltd., for the loan of the apparatus. Permission to publish the results of the investigation has been granted by the British Iron and Steel Research Association.

Appendix

The standard deviations and coefficients of variation shown in Table II were calculated as follows :—

$$\text{Standard Deviation, S.D.} = \sqrt{\frac{\Sigma d^2}{n-1}}$$

$$\text{Coefficient of Variation, C.V.} = \frac{\text{S.D.}}{C} \times 100$$

where d = deviation from the mean
n = number of determinations
C = mean percentage concentration.

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An Oblique Illuminator for Use in Hardness Testing

By S. A. Dunk*

A description is given of an experimental model of an inexpensive oblique illuminator which has some advantages in the examination of hardness test indentations.

IT is sometimes necessary to carry out Brinell hardness tests using a 1 or 2 mm. ball indenter and loads of up to 120 kg. The indentations made during these tests are commonly measured with a metallurgical microscope fitted with a micrometer eyepiece, and are viewed under vertical illumination, giving a dark image of the impression on a bright field of view. This type of illumination differs from that used in measuring the large indentations produced in 3,000 kg. Brinell hardness tests, in which diffused oblique illumination is generally employed.

Experience at this laboratory has shown that, under vertical illumination, it is possible for the measured Brinell hardness of a soft steel specimen to depart from the known hardness by as much as 10%. The error is caused by the particular angle at which the incident light strikes a ring of disturbed metal surrounding the impression, making this ring of metal appear to the observer as part of the indentation. The apparent diameter of the impression increases as the aperture of illumination decreases, and hence any error is most likely to occur when using low-power objectives. This effect may be seen in an exaggerated form in annealed copper, where the diameter of the impression may appear to be as much as 20% larger than its true value.

This type of error is generally not present in pyramidal hardness testing, as any induced straining of the test surface takes place along the sides of the impression, and is very small in the vicinity of the corners; hence the observed distance across the corners is the true diagonal of the impression.

It has been found (Ellis, unpublished data) that difficulty in determining the true edge of a small Brinell impression may be avoided by viewing it under oblique illumination from a diffuse source, which is similar to the lighting used in the low-power microscopes with which large Brinell indentations are usually measured. The present unit provides a simple means of achieving this result.

* Division of Metrology, National Standards Laboratory, C.S.I.R.O., Melbourne.

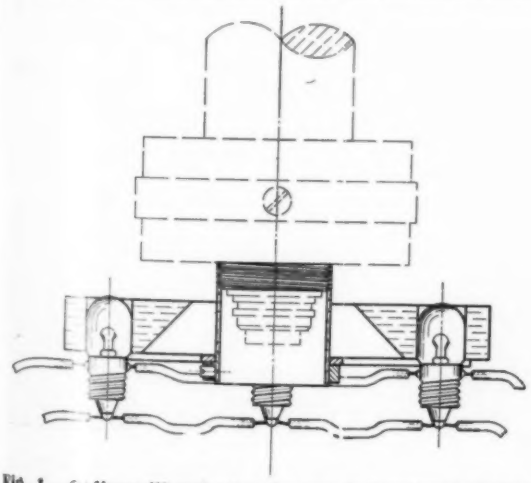

Fig. 1.—Oblique illuminator for use in hardness testing.

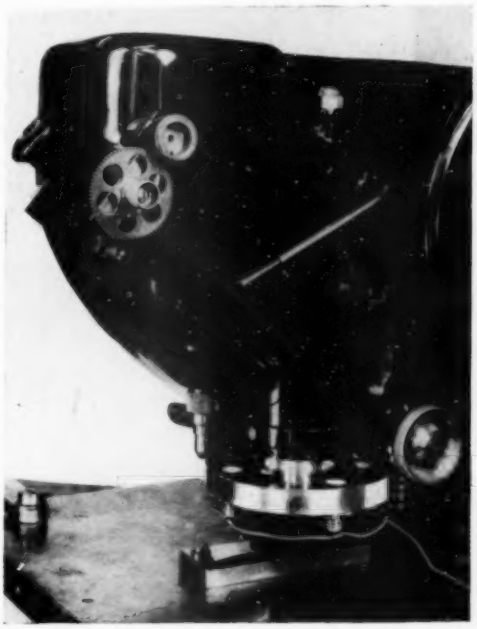

Fig. 2.—Vickers hardness testing machine microscope with illuminator attached.

Construction

The illuminator consists of a ring of Perspex, 4 in. outside diameter × $1\frac{3}{4}$ in. bore × $\frac{1}{2}$ in. thick. Four equally spaced holes are drilled at 3 in. pitch circle diameter to take 6V., 0·3A. radio panel lamps as an easy push fit (see Fig. 1). The bore of the annulus is chamfered at about 45°, and is sandpapered to a matt finish to provide a suitable diffusing surface. All other surfaces are highly polished to reduce loss of light. The circumference of the ring is aluminised, but this refinement may be omitted as the effect of light escaping radially outward may be compensated for by fitting additional globes.

The ring is mounted on a spider which, in the present case, is attached to the lens guard of the measuring microscope. Fig. 2 shows the assembly fitted to a Vickers hardness testing machine. In this particular application, it may be attached or removed without disturbing any existing equipment, and is locked in place by tightening a grub screw.

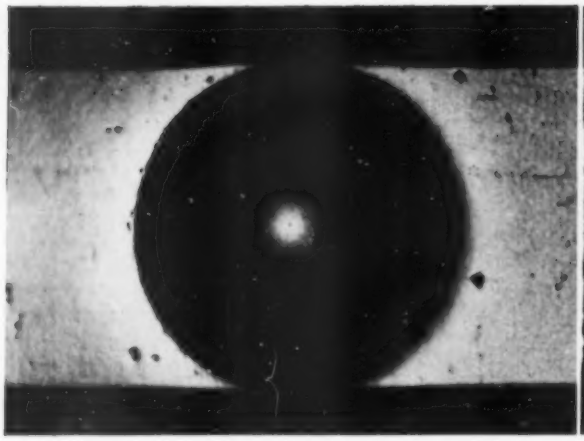

Fig. 3.—Brinell hardness impression made at 120 kg. load and with 2 mm. ball indenter, on a polished steel test block having a diamond pyramid hardness of 200, viewed under vertical illumination.

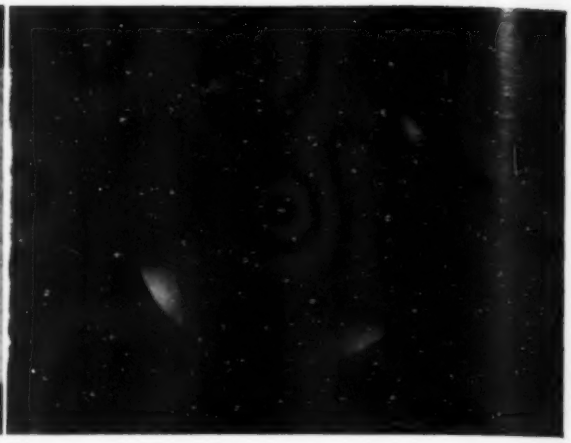

Fig. 4.—The same impression as that seen in Fig. 3, but viewed under oblique illumination.

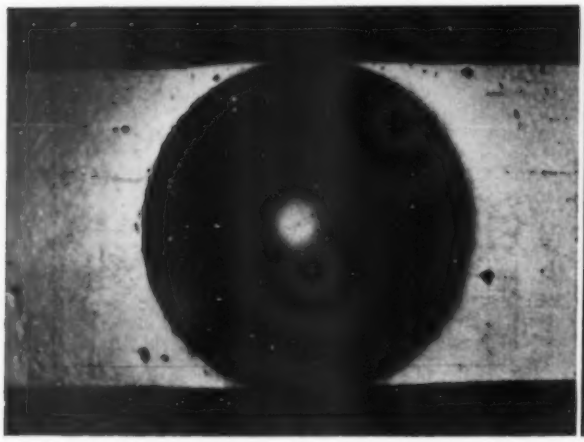

Fig. 5.—The same impression as that seen in Fig. 3, but viewed under combined vertical and oblique illumination.

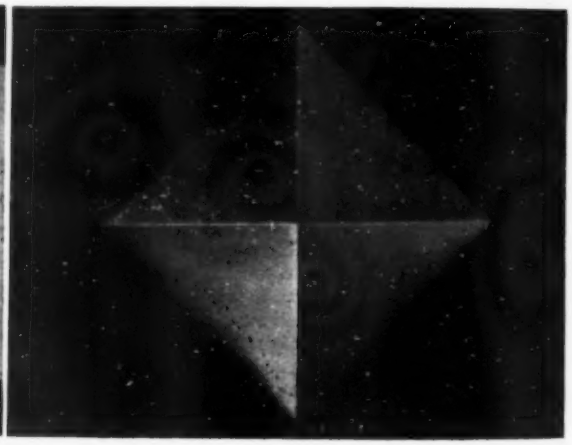

Fig. 6.—Diamond pyramid hardness impression on a specimen with a polished surface, viewed under oblique illumination.

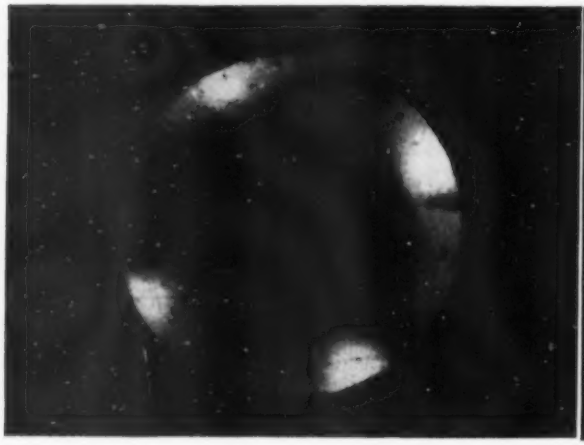

Fig. 7.—Brinell hardness impression on a specimen with a matt surface, viewed under oblique illumination.

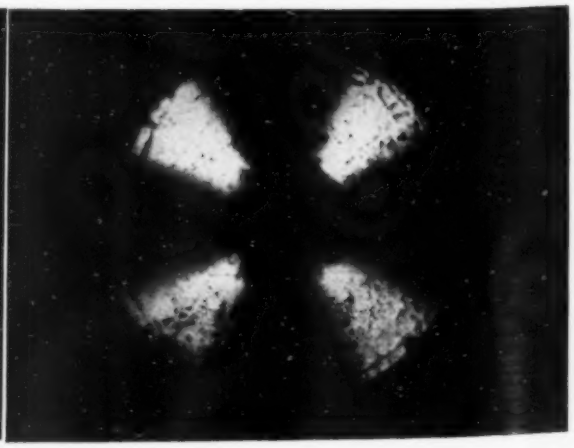

Fig. 8.—Impression made by a pitted and out-of-round diamond cone, viewed under oblique illumination.

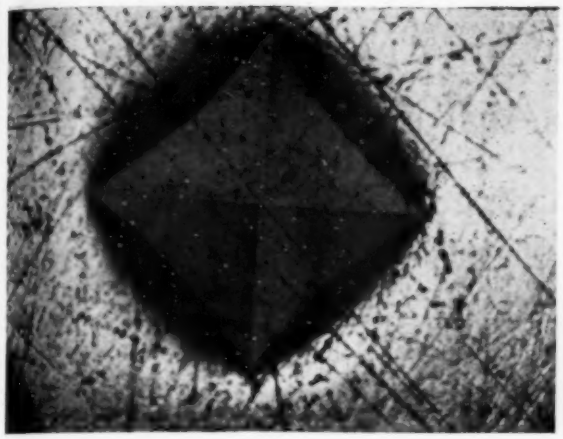

Fig. 9.—Diamond pyramid hardness impression on an imperfectly polished surface on annealed copper, viewed under combined oblique and vertical illumination.

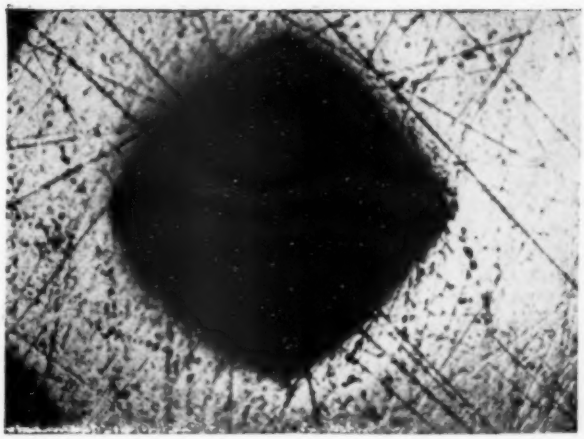

Fig. 10.—The same impression as that seen in Fig. 9, viewed under vertical illumination.

Applications

Figs. 3, 4 and 5 show views of the same Brinell impression under vertical, oblique, and combined vertical and oblique illumination, respectively. This indentation was made using a load of 120 kg. and a 2 mm. ball indenter on a polished steel test block having a diamond pyramid hardness of 200. The shutters of the micrometer eyepiece were set so that one coincided with the apparent edge of the impression as seen under vertical illumination, and the other with the true edge, i.e., the inner edge of the ring of disturbed metal surrounding the impression. Fig. 5 clearly shows this ring of disturbed metal, which appears to be part of the impression when viewed under vertical illumination alone (Fig. 3).

A disadvantage of oblique illumination on a polished specimen is that it shows a bright image of the impression on a dark field of view (Figs. 4 and 6) making it very difficult to distinguish the micrometer shutters from the background. This difficulty may be avoided either by using both forms of illumination together, as in Fig. 5, or by using oblique illumination in conjunction with a matt test surface (Fig. 7).

The illuminator has also been used as a rapid means of locating surface defects in diamond indenters. Fig. 8 shows an impression made by a pitted and out-of-round diamond cone in which irregularities on the flank of the impression caused by defects in the indenter surface can be clearly seen. Cracks in diamond pyramid indenters also have been detected in this manner. For this application, a highly polished test surface is desirable, as there is then less likelihood of mistaking surface irregularities originally present (Fig. 9) for those caused by imperfections in the indenter.

When used in conjunction with vertical illumination, this device clearly shows the relation of an indentation to disturbed metal in its immediate vicinity (Fig. 9). When the indentation is viewed under vertical illumination alone, as in Fig. 10, its true shape may be difficult to determine. This may be of interest where, as suggested in B.S. 427, the shape of a diamond pyramid indentation is used to indicate the capacity of a material for cold work. The material illustrated in Figs. 9 and 10 is annealed copper.

The illumination provided by this device is not truly uniform, as unavoidable leakage causes highlights in spherical and conical impressions. However, the variation in intensity is not large enough to inconvenience visual examination of hardness impressions.

Acknowledgments

The work described in this paper was carried out as part of the programme of the Division of Metrology, Commonwealth Scientific and Industrial Research Organization. The author wishes to thank Mr. R. J. Ellis, who drew the author's attention to the need for an oblique illuminator, Mr. R. E. Aitchison, who suggested the possibility of using Perspex as a diffuser, and Dr. W. H. Steel, who investigated the cause of the variation in apparent diameter of small impressions under vertical illumination.

Nickel Import Duty

THE Treasury have made an Order which continues for a further period of one year from May 13th, 1956, the exemption from duty under the Import Duties Act, 1932 of certain forms of nickel and ferro-nickel alloys imported in the forms described in the Schedule to the Import Duties (Exemptions) (No. 3) Order, 1955. (S.I. No. 676). Copies of this new Order, the Import Duties (Exemptions) (No. 5) Order, 1956 (S.I. No. 684), may be obtained from Her Majesty's Stationary Office, or from any bookseller (price 2d.; by post 3½d.).

Export Order for Birlec

To be supplied to the Corporation Minera de Bolivia at Catavi, Bolivia, (an enterprise owned by the Bolivian Government) is a Birlec Lectromelt furnace for making steel castings. The furnace—of 3 ton capacity with a rating of 1,500 kVA—is to be built 12,280 ft. above sea level,and will almost certainly be the highest melting furnace installation in the world. At this elevation, cooling of the various motors and ancillary equipment is less efficient than at normal levels and, consequently, special precautions are to be taken.

Liquid-Liquid Extraction Procedures in Inorganic Analysis

A Review of Practical Applications with Particular Reference to Metallurgical Analysis

By T. S. West, B.Sc., Ph.D., A.R.I.C.

Department of Chemistry, University of Birmingham.

The growing complexity of modern materials has led to difficulties in their chemical analysis resulting from the increasing multiplicity of other substances accompanying the constituent to be determined. The development of new separation methods has made possible the continued use of classical analytical procedures in the face of increasing competition from physical methods, and in the present series of articles the author surveys liquid-liquid solvent extraction techniques in inorganic analysis, with particular reference to metallurgical analysis. In the fifth of the series, the author discusses the extraction of Group V metals.

(*continued from page* 240 *of the May issue of* METALLURGIA).

EXTRACTION OF GROUP Va METALS (V, Nb, Ta)

Vanadium

HILLEBRAND and Lundell[76] and Lundell, Hoffman and Bright[77] state that only a trace of vanadium accompanies ferric iron in the diethyl ether extraction of ferric chloride from 6N hydrochloric acid. This is particularly the case when the vanadium is in the quadrivalent state, but they indicate that a considerable fraction of vanadium^{V} is extracted. Using diisopropyl ether, Dodson, Forney and Swift[78] found that less than 0·08% of vanadium^{IV} was extracted from 7·75M hydrochloric acid by an equal volume of the solvent, but 22% was extracted from pentavalent vanadium solutions. Lingane and Meites[79] point out that in acid solution the pervanadyl ion can exist almost entirely as the uncharged polyvanadic acid $H_4V_6O_{17}$, depending on the acid concentration, whereas the quadrivalent ion exists only as the simple $VO^{2}_{2}{}^{+}$ ion. The solubility of the polyvanadic ion in the ether is not surprising. Lingane and Meites found that quadrivalent vanadium is not extracted from aqueous acid solutions when peroxides are not present in the ether, but that when a freshly prepared vanadium^{V} solution is extracted by isopropyl ether, the concentration of vanadium in the ether layer is initially relatively large, but decreases rapidly with time due to slow reduction by the chloride ion. The distribution coefficient for vanadium^{V} between diisopropyl ether and hydrochloric acid of various strengths at 25° C. is 0·028 in 6M acid, 1·2 in 7·5M acid and 1·03 in 8·5M acid. The extratacbility of both forms of vanadium increases with diminishing temperature. The value of the distribution coefficient of vanadium^{V} from 8M acid is 2·40 at 0°, 1·29 at 25° and 0·04 at 45·6°. It is not known whether vanadium is extracted from iodide or bromide solutions. According to Wells and Hunter,[80] amyl acetate is a superior solvent to diethyl ether for the extraction of vanadium, removing some 14% from concentrated hydrochloric acid solution. Small amounts, *ca* 2%, of vanadium are extracted from 8N nitric acid by diethyl ether. Vanadium has been extracted as molybdovanadophosphoric acid by diethyl ether, 3 methyl-1-butanol, mixtures of *n*-butanol with ether, butanol, butyl acetate, etc.[81, 82]

Vanadium^{V} cupferrate is completely extracted from 10% hydrochloric acid by ethyl acetate, and even microgram amounts are completely removed from 10% sulphuric acid solution by ether and cupferron.[17] Montequi and Gallego[83] used extraction of quinquevalent vanadium by oxine in chloroform from a weakly acid solution (*p*H 4–5) as a means of isolating small amounts of vanadium. Ferric iron and molybdenum^{VI} are co-extracted, but a good separation is obtained from chromium.^{VI} Vanadium is not extracted by dithizone and chloroform.

Niobium and Tantalum

As far as is known, niobium and tantalum are not extracted by diethyl ether from either nitric or hydrochloric acid solutions, but both metals have been found to extract from aqueous solutions containing hydrochloric and hydrofluoric acids into certain polar solvents[84, 85]. Stevenson and Hicks[86] took up this earlier work, using diisopropyl ketone as solvent. Tantalum is more readily extracted than niobium. The extraction was carried out from solutions containing hydrofluoric acid and each of the common mineral acids in turn. A mixture of sulphuric and hydrofluoric acids was found to offer the best separation and purification of tantalum and niobium. From a solution 6N in hydrochloric acid and 0·06M in hydrofluoric acid, the ketone extracted more than 90% tantalum. The first table shows the extraction of niobium and tantalum from acids of various strengths.

In particular, it reveals that whilst the sulphuric-hydrofluoric acid system gives the optimum extraction of niobium and tantalum, the system using nitric acid is by far the best for separating the two. In all cases cited above, only small amounts of niobium are extracted. In a solution about 6M in sulphuric acid and

EXTRACTION OF NIOBIUM AND TANTALUM FROM VARIOUS ACID MIXTURES

Acid System	Concentration	Element	% Extracted	Partition Coefficient	Separation Factor
Hydrochloric Hydrofluoric	3·70 0·40	Tantalum Niobium	81 4·5	4·3 0·047	91
Nitric Hydrofluoric	3·92 0·40	Tantalum Niobium	79 0·43	3·8 0·0043	880
Sulphuric Hydrofluoric	4·50 0·40	Tantalum Niobium	95 11	19 0·12	160
Perchloric Hydrofluoric	4·61 0·40	Tantalum Niobium	90 3·0	9·0 0·031	290

9M in hydrofluoric acid, as much as 90% of niobium is extracted into an equal volume of ketone, whilst from 3M sulphuric acid and 4·5M hydrofluoric acid solution, 40% of niobium is removed into the organic solvent. Stevenson and Hicks claimed that tantalum was completely extracted from 6M sulphuric acid—0·4M hydrofluoric acid with only elemental halogens, selenium[VI] and tellurium[VI] in attendance. From 6M hydrochloric acid—0·4M hydrofluoric acid, iron,[III] gallium,[III] antimony[V] and arsenic[III] are extracted in addition to the above. All but antimony[V] are back extracted into water. Antimony,[III] arsenic,[V] and tellurium[IV] extract slightly, and selenium[IV] is scarcely extracted at all. It is significant that silicon, tin, titanium, manganese, zirconium, hafnium, etc., which usually accompany niobium and tantalum, do not extract.

In their review of the extraction of cupferrates, Furman, Mason and Pekola[17] observe that whilst niobium cupferrate is not appreciably soluble in chloroform, considerable amounts of niobium are transferred to the organic phase when an aqueous solution of the metal is shaken with a solution of cupferron in chloroform. They do not comment on the extractability of tantalum cupferrate, although one may infer that it also may be extracted, since it precipitates under almost identical conditions.

Leddicotte and Moore[87] found that niobium may be extracted virtually completely from strong hydrochloric acid by means of a solution of methyldioctylamine in xylene, under conditions such that the extraction of tantalum is negligible. The niobium may be back extracted from the organic solvent by shaking the latter with dilute hydrochloric acid, nitric acid or sulphuric acid. The best separation of the two metals was found to take place from 8N hydrochloric acid. Under these conditions 99·3% of the niobium was extracted with only *ca* 1% of the tantalum. These authors make the following most interesting observations. Niobium is not extracted appreciably from nitric acid in concentrations up to 10·6M, and from sulphuric acid up to 12M. Tantalum does not extract from up to 10·6M nitric acid or from strong solutions of sulphuric acid. It is, however, extracted to some considerable extent from 2M sulphuric acid. These studies were carried out at concentrations not greater than 1 mg./ml.

Scadden and Ballou *loc. cit.* have studied the solvent separation of zirconium from niobium, using a solution of mixed butyl phosphoric acids in butyl ether, and have indicated that a separation of macro concentrations of niobium from tantalum is possible. The extraction appears to merit detailed examination.

EXTRACTION OF NIOBIUM AND TANTALUM BY 5% METHYLDIOCTYLAMINE IN XYLENE FROM AQUEOUS HYDROCHLORIC ACID.

Hydrochloric Acid Normality	2·9	3	4	4·85	6	7·28	8	8·85	9·6	10·10	11·2
% Extraction Niobium	—	2·4	2·2	—	21·5	—	99·3	—	100	—	—
Tantalum	0·25	—	—	0·11	—	0·55	—	1·10	—	1·35	1·40

EXTRACTION OF GROUP Vb METALS (As, Sb, Bi)

Arsenic

Arsenic[III] is extracted from 6N hydrochloric acid to the extent of 68% by diethyl ether. When the arsenic is present in the pentavalent state, however, only 2–4% is extracted. No information is available on the ether extraction of arsenic from iodide or bromide solutions, but West and Carlton[40] have noted that it is partially extracted by methyl isopropyl ketone from a 5% hydrochloric acid solution containing excess of potassium iodide. Kitahara[37] reported that 62% of arsenic may be extracted from hydrofluoric acid by diethyl ether when the acid concentration is 40%. Only 44% is extracted from 20% hydrofluoric acid. Arsenic[V] is extracted to the extent of 14% by diethyl ether from 8N nitric acid.

Furman, Mason and Pekola[17] observe that neither trivalent nor pentavalent arsenic is precipitated by cupferron. Strafford, Wyatt and Kershaw[3] made use of the extractability of the diethyldithiocarbamate compound of arsenic[III] to separate it from lead, zinc, cadmium, nickel, cobalt, iron, etc. The extraction takes place from acid solution, using chloroform as the solvent. When the arsenic is in the pentavalent form it is not extracted by this operation. Copper, bismuth, and the noble metals, which accompany the arsenic[III] can therefore be removed in an initial extraction after oxidation of the arsenic. When sodium diethyldithiocarbamate is used as the reagent, incomplete extraction occurs, but Luke and Campbell[88] have recently confirmed the findings of Strafford and his co-workers, who were able to obtain quantitative extraction from 2N hydrochloric acid by using diethylammonium diethyldithiocarbamate as the reagent in conjunction with chloroform as the solvent. Klein and Vorkes[89] found that arsenic[III] could be extracted from acid solution as the xanthate by carbon tetrachloride. Antimony and other metals extracted as xanthates were readily removed from the extract by shaking with concentrated hydrochloric acid containing stannous chloride. According to Sandell,[29] aluminium, manganese, zinc, lead, mercury, cadmium, and bismuth do not interfere. Amounts of arsenic of the order of 0·1 mg. are said to give excellent recoveries. In reviewing the literature on the extraction of heteropoly acids, Wadelin and Mellon[75] quote the work of Farrer and Muir[90] and of Mervel,[91] who found that a mixture of 1-butanol and chloroform selectively extracts phosphorus as molybdophosphoric acid in the presence of arsenic and silicon. The procedure was later extended[92, 93] to treating the raffinate with a mixture of 1-butanol and ethyl ether to extract the molybdoarsenic acid, and finally with 1-butanol to extract the molybdosilicic acid. Arsenic cannot be extracted by either dithizone or oxine in chloroform.

Antimony

Antimony is readily extracted from hydrochloric acid (6N) by diethyl ether, but in contrast to the behaviour of arsenic, the higher oxidation state is more readily extracted than the lower one (81% as opposed to 66%). It will be seen, however, that the solvent is not a selective in its action as it is with arsenic. Under the most

favourable conditions for separating the two forms of antimony, Mylius and Huttner[21] obtained 85% extraction of antimony^{v} and 6% of antimony.^{III} Edwards and Voigt[94] applied isopropyl ether to the extraction. When only antimony^{v} is present, 98% extraction occurs over the range 3–9N hydrochloric acid. When both forms are present, a single extraction from 6·5–8·5N acid concentrates all the pentavalent antimony with only 2% of the trivalent form in the organic layer. A single distribution between the organic layer and 6·5–8·5N hydrochloric acid then leaves all the pentavalent antimony in the ether layer, with only 0·04% of the antimony^{III} content of the original solution.

Antimony^{III} is completely extracted from 6·9N hydriodic acid solution by diethyl ether according to Kitahara,[36] and less than 50% is removed from 1·5N acid according to Irving and Rossotti.[38] Only small amounts (0·4%) are extracted from 30% hydrofluoric acid solution. A similar amount is extracted from 8N nitric acid. West and Hamilton[95] found that the tetraiodoantimonate^{III} ion was completely extracted from acid solution by benzene. White and Rose[96] have more recently used ethyl acetate in conjunction with a mixture of oxalate and citrate as complexing agents to remove antimony^{v} from 1–2N hydrochloric acid. Iron, tin, copper, cadmium, lead, etc., were not extracted, but traces of arsenic, bismuth, and molybdenum, and large amounts of silver, mercury, and gold, accompany the antimony into the extract. The procedure was applied successfully to the analysis of alloys.

Cupferron and chloroform do not extract antimony^{v} from acid solution, but quantitative removal of the trivalent form takes place from 10% sulphuric acid.[17, 97] Luke and Campbell[88] made use of this extraction to separate antimony from thallium[1] and iridium. The iron which accompanied the antimony under the conditions employed by these authors was eliminated by oxidising the antimony and re-extracting with cupferron and chloroform.

The rhodamine B complex of antimony is readily extracted into benzene, particularly after addition of a little butyl cellosolve. The extract is highly coloured and the extraction is therefore much used in absorptiometry. Dithizone is ineffective in extracting antimony, and it is not certain to what extent the precipitate formed with 8-hydroxyquinoline is extractable. Gentry and Sherrington[16] state that its extraction may be suppressed by means of tartrate. As mentioned previously, the xanthate may be extracted by carbon tetrachloride.

Bismuth

Bismuth is not extracted from 6N hydrochloric acid by diethyl ether, although small amounts (6—8%) are extracted from 8N nitric acid solution. Little information is available on the extraction of bromide, but the iodide is known to be soluble in several organic solvents. Thus 34·2% of bismuth may be extracted from 6·9N hydriodic acid by diethyl ether,[36] and less than 10% from 1·5N acid. West, Senise and Carlton[98] used methylisobutyl ketone to extract the BiI_4^- ion from aqueous solution in a qualitative spot test procedure. The acidity is said not to be critical. Bismuth may also be extracted from aqueous solutions containing ammonium thiocyanate. Diethyl ether does not extract bismuth from fluoride[37] solution.

Bismuth cupferrate is quantitatively precipitated from hydrochloric and sulphuric acid solutions. The precipitate is soluble in toluene or methyl ethyl ketone. The extraction of the dithizonate has been the subject of much investigation. The extraction of the complex becomes incomplete in strongly basic solution. Fischer[99] recommends *p*H 7–8 for extraction with carbon tetrachloride. The presence of cyanide in the aqueous solution does not prevent extraction of the bismuth. This allows bismuth to be separated from other metals forming extractable dithizonates, apart from lead, thallium, and tin.[11] The lead and thallium dithizonates are not so stable towards mineral acid as the bismuth complex. Bismuth diethyldithiocarbamate is readily extracted by diethyl ether from acid solution[100] and according to Lacoste, Earing and Wiberley[101] the extraction with chloroform is independent of *p*H in the range 1–8.

Using a 0·01M solution of oxine in chloroform, Moeller[15] obtained complete extraction of bismuth in the range *p*H 4·0–5·2, whereas Gentry and Sherrington[16] found that partial extraction was obtained from *p*H 5–12 by using a 1% (0·07M) reagent.

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Business News

FIRTH BROWN TOOLS, LTD., have changed the address of their Manchester Office to Speedicut House, Royle Street, Fallowfield, Manchester 14. The new premises include an extensive warehouse where stocks of engineers' cutting tools will be carried for the convenience of customers in the Manchester area.

FIELDEN ELECTRONICS, LTD., the industrial instrumentation specialists of Wythenshawe, Manchester, have appointed A. R. Bolton, Ltd., 72 Haymarket Terrace, Edinburgh 12. (Tel: 62446) to be their sole Scottish agents. The appointment has been in force since May 1st.

VICKERS LTD., are acquiring 75% interest in Hoskins Engineering & Foundry Pty., Ltd., of Perth, Western Australia, a well-known company engaged in general engineering work.